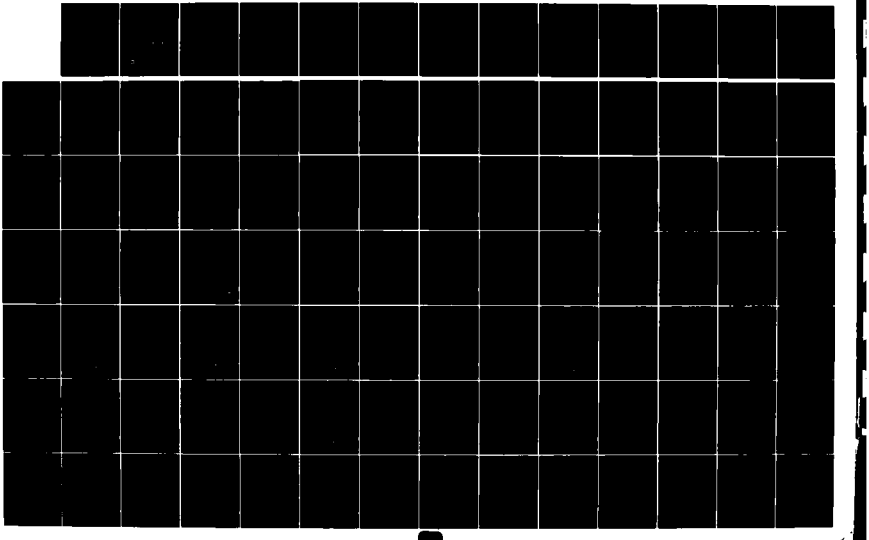
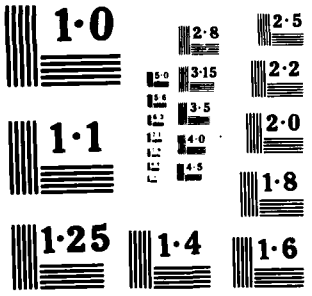
AD-A163 285 CONSTRUCTION FOUNDATION REPORT GRAND RIVER BOWMAN-HALEY 1/2
PROJECT NORTH DAKOTA VOLUME 1 TEXT DRAWINGS PHOTOS(U)
CORPS OF ENGINEERS OMAHA NE MAY 85

UNCLASSIFIED F/G 13/13 NL




1·0
1·1
1·25
2·8
3·15
3·5
4·0
4·5
2·5
2·2
2·0
1·8
1·4
1·6

CONSTRUCTION FOUNDATION REPORT

AD-A163 265

GRAND RIVER
BOWMAN-HALEY PROJECT
NORTH DAKOTA

VOLUME I
TEXT
DRAWINGS
PHOTOS

DTIC
ELECTE
JAN 23 1986
S D
D

THE FILE COPY

MAY 1985

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

US Army Corps
of Engineers
Omaha District

85 12 17 129

Project C12289
Disk 226-C

CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA

TABLE OF CONTENTS

Paragraph	Title	Page
	CHAPTER 1 - INTRODUCTION	
1.1	Location and General Description of Project	1-1
1.2	Authority	1-2
1.3	Purpose of Report	1-3
1.4	Project History	1-2
1.5	Contractors	1-4
1.6	Key Staff	1-4
	CHAPTER 2 - FOUNDATION EXPLORATION	
2.1	Foundation Explorations	2-1
	CHAPTER 3 - GEOLOGY	
3.1	Regional Geology	3-1
3.2	Site Geology	3-1
3.3	Engineering Characteristics of Overburden	3-2
3.4	Engineering Characteristics of Bedrock	3-4
3.5	Unusual or Unanticipated Geologic Conditions Encountered During Construction	3-5
	CHAPTER 4 - SPECIAL DESIGN CONSIDERATIONS	
4.1	Embankment Foundation Cutoff Trench	4-1
4.2	Permeability of Lignites that Underlie the Embankment	4-5
4.3	Spillway Fuse Plug Foundation	4-7
4.4	Spillway Scour Cutoff	4-7
	CHAPTER 5 - EXCAVATION PROCEDURES FOR COMPONENT PARTS	
5.1	Excavation Grades	5-1
5.2	Dewatering	5-1
5.3	Overburden Excavation	5-1
5.4	Rock Excavation	5-1
5.5	Spillway Excavation	5-1
5.6	Foundation Preparation	5-1
5.7	Safety	5-2

CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA

TABLE OF CONTENTS (Cont'd)

Paragraph	Title	Page
	CHAPTER 6 - TUNNELS, SHAFTS, AND UNDERGROUND STRUCTURES	
6.1	Intake Conduit	6-1
	CHAPTER 7 - CHARACTER OF FOUNDATION	
7.1	Foundation Surface	7-1
7.2	Previous Foundation Discussion	7-1
7.3	Water	7-1
7.4	Special or Unusual Conditions	7-1
	CHAPTER 8 - FOUNDATION INSTRUMENTATION	
8.1	General	8-1
8.2	Piezometers	8-1
8.3	Crest Movement Markers	8-1
8.4	Conduit, Stilling Basin, and Intake Markers	8-1
8.5	Automatic Piezometer Monitoring System	8-1
	CHAPTER 9 - POSSIBLE FUTURE PROBLEMS	
9.1	Conduit Leakage	9-1
9.2	"A" Lignite	9-1

TABLE OF CONTENTS - TABLES

Table No.	Description	Page
1	Atterberg Limits - Overburden	3-5
2	Shear Strength Values	3-6
3	Drained and Undrained Strengths	3-7
4	Cutoff Trench, Field Compaction Tests	4-3
5	Water Pressure Test Results, "A" Lignite	4-8

Accesion For
NTIS CRA&I
DTIC TAB
Unannounced
Justification
By
Distribution /
Availability Codes
Dist | Avail and / or Special
A-1

CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA

TABLE OF CONTENTS - PLATES

Plate No.	
1	Project Location Map
2	General Plan and Area Use
3	Area Geologic Map
4	Plan of Borings
5	Record of Borings, Section A-A, and Boring Legend
6	Record of Borings, Section B-B
7	Record of Borings, Sections C-C, D-D, and E-E
8	Record of Borings, Sections F-F, G-G, and Borrow Area
9	Soil Profile, Embankment Centerline
10	Record of Borings, Spillway Section and Profile
11	Record of Borings, Piezometer and Pressure Test Holes
12	Outlet Works Conduit - Record of Borings
13	Foundation Soil Test Data - Clayey Sand (Ludlow)
14	Foundation Soil Test Data - Lean and Fat Clay (Ludlow)
15	Foundation Soil Test Data - Lean and Fat Clay (Overburden)
16	Spillway Profile (Sections and Details)
17	Spillway Grading Plan
18	Piezometer Sections - "A" Lignite
19	Embankment Sections
20	Embankment Profile, Spillway Section
21	Embankment Drain - Profile, Section and Detail
22	Outlet Works - Sections
23	Piezometer Observations - "A" Lignite Layer
24	Plan - Seepage Measurement Station
25	Seepage Flow Observations
26	Piezometer Profile, "A" Lignite
27	Piezometer Profile, "A" Lignite
28	Piezometer Profile, "A" Lignite
29	Embankment Crest Markers, Vertical and Horizontal Movement
30	Embankment Crest Movement Markers, Vertical Movement
31	Outlet Works, Vertical Movement
32	Automatic Piezometer Monitoring System, Location Plan
33	Automatic Piezometer Monitoring System, Piezometer Detail
34	Automatic Piezometer, Specifications

CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA

TABLE OF CONTENTS - PHOTOS

Photo No.	
1	Site Prior to Construction, July 1964
2	Cutoff Trench Excavation, September 1966
3	Cutoff Trench Excavation, September 1966
4	Cutoff Trench, Backfill Operations, September 1966
5	Cutoff Trench Excavation, September 1966
6	Cutoff Trench Excavation, September 1966
7	Cutoff Trench Excavation, September 1966
8	Cutoff Trench Excavation, September 1966
9	Cutoff Trench Excavation, September 1966
9A	Cutoff Trench Excavation, September 1966
9B	Cutoff Trench Excavation, September 1966
10	Conduit Construction
11	Trenching for Outlet Works, September 1966
12	Upstream Portion of Stilling Basin with Fill on Conduit
13	Stilling Basin with Backfill Placement, October 1966
14	Stilling Basin, August 1966
15	Stilling Basin, Foundation and Slab
16	Stilling Basin, Pouring Foundation Slab, August 1966
17	Spillway, Soil - Cement Scour Cutoff, September 1966
18	Spillway, Placing Soil - Cement in Scour Cutoff Trench, September 1966
19	Spillway, Showing Lignite in Scour Cutoff Trench, September 1966
20	Spillway, Excavation of Scour Cutoff Trench, September 1966
21	Outlet Works, Invert Collar Excavation, September 1964
22	Outlet Works, Conduit Collar Invert Excavation, August 1964
23	Outlet Works, Backfilling Conduit, November 1964
24	Concretionary Rock Encountered in Spillway Excavation, April 1967
25	Concretionary Rock In-Place on Spillway Slope, April 1967

CONSTRUCTION FOUNDATION REPORT
BOWMAN-HALEY DAM
MISSOURI RIVER BASIN, NORTH DAKOTA

CHAPTER 1. - INTRODUCTION

1.1 **LOCATION AND GENERAL DESCRIPTION OF PROJECT:** The Bowman-Haley Project is located on the north fork of the Grand River in a sparsely settled area in southwestern North Dakota. The north fork basin is bounded by the Little Missouri River on the west and north. Other Grand River tributaries bound the basin to the east and south. The project is about 6 miles upstream (west) of the town of Haley, North Dakota. The geographic location of the project is shown on Plate 1. The project layout is shown on Plate 2.

The following tabulation summarizes pertinent data for the project's structure, the reservoir, and flood design:

Drainage Area

Above Bowman-Haley Damsite - 471 square miles.

Reservoir Area

	El., ft. m.s.l.	Acres
Top of Design Pool	2789.0	8130
Top of Controlled Storage	2781.0	6050
Top of Flood Control Pool	2777.0	5170
Top of 5-year Freq. Flood Control Pool	2758.3	2200
Top of Multi-purpose Pool	2755.0	1750

Storage Capacity	Acre-Feet
Total @ 2789 m.s.l.	171,838
Gross Controlled Storage @ 2781.00	113,940
Flood Control @ Spillway Crest of 2777.0 m.s.l.	92,980
Multi-purpose	19,780
Sediment reserve	4,280

Elevations	Feet, m.s.l.
Top of Dam	2794.0
Multi-purpose Pool	2755.0
Maximum Pool	2789.0
Emergency Spillway Crest	2777.0
Top of Fuse Plug	2781.0

Dam

Type	Rolled Earth Fill
Maximum height above River	79.0 feet
Crest Length	5,730 feet
Fill Quantity	1,750,000 Cu. Yds.

Emergency Spillway

Type	Uncontrolled notch
Bottom Width	650 feet
Side Slopes	1 on 3
Crest Elevation	2,777 ft., m.s.l.
Top of Fuse Plug	2,781 ft., m.s.l.

Service Spillway

Type	Uncontrolled morning glory
Throat diameter	9.0 feet
Conduit diameter	10 feet
Conduit length	341 feet
Crest elevation	2,755 ft., m.s.l.
Upstream invert elevation (P.T.)	2,720.51 ft., m.s.l.
Downstream invert elevation	2,712.0 ft., m.s.l.
Capacity, Pool El. 2773	2,555 c.f.s.
Capacity, Pool El. 2781	2,900 c.f.s.

Stilling Basin

Width	25 feet
Length - Drop Section	57 feet
Length - Basin	59 feet
Floor Elevation	2,700 ft., m.s.l.

Outlet Works

Type	Wet well forebay; gate control in dry well; discharge into spillway conduit
Conduit diameter	30 inches
Capacity, Multi-purpose pool	140 c.f.s.
Control	30-inch gate valve
Trashrack Invert Elevation	2,740 ft., m.s.l.

1.2 AUTHORITY: The project was authorized by the Flood Control Act of 1962, H.D. 574/87/2, for the purpose of flood control, municipal water supply, general recreation and fish and wildlife recreation. Full monetary authorization for the project was provided by the act which authorized the project.

1.3 PURPOSE OF REPORT: This report has been prepared in accordance with requirements set forth in Regulation No. 1110-1-1801, Engineering and Design Construction Foundations Reports, Office, Chief of Engineers dated 14 January 1972. The purpose of the report is to compile a record of the foundation conditions encountered for the various structures comprising the Bowman-Haley Project. Included are pertinent data concerning the site geology, explorations, engineering characteristics of overburden and bedrock, excavation methods, foundation treatment, instrumentation and other related subjects. Also included are supplemental drawings, logs, test data and photographs. Detailed information concerning materials testing, stability analysis, and other foundation design data relating to the project are available from the numerous files of the Omaha District Office and are not repeated in this report.

1.4 PROJECT HISTORY: Initial local interest in the project was expressed at public hearings which were held at Lemmon, South Dakota (April, 1945) and Bowman, North Dakota (August, 1956) with regard to flood protection and municipal and irrigation water supply. State and local interests later excluded irrigation water supply as a requirement for the project.

1.4.1 Design Memo No. BH-1, "Hydrology" dated January 1963, was prepared by Omaha District and in February, 1964, a revised General Design Memorandum No. BH-2 was submitted by the District to higher authority. Design Memorandum No. BH-2 specified the extent and location of major features of the project. Final design for structures of the project is covered in Design Memorandum No. BH-5, October, 1964. This report covers the design of the embankment, emergency spillway, outlet works and road/utility relocations and alterations. All Design Memorandums are available in the Omaha District Office.

1.4.2 Initial borings (four) were drilled at the right bank spillway location in the Fall of 1959. In 1963, 29 additional borings were drilled for the embankment centerline, outlet works, right bank spillway and an alternate spillway location on the left bank. Boring locations are shown on Plate 4.

1.4.3 The work for the outlet works service spillway conduit was awarded on 30 June 1964; construction for the conduit started July 1964 and was completed December 1964.

1.4.4 The work for the dam and appurtenant structures (including the spillway intake structure and stilling basin), was awarded in June 1965. Construction was originally scheduled for two construction seasons. The first construction period started in August 1965 and was completed in November 1965. The second construction period began in April 1966 and ended in July 1967. A claim which alleged unanticipated rock excavation (for the spillway) resulted in the project extending into a third construction period.

1.4.5 Closure operations began on 22 August, 1966 and were essentially complete by 19 December 1966.

1.5 **CONTRACTORS:** Brezina Construction Company of Rapid City, South Dakota was the Contractor for the entire project.

1.6 **KEY RESIDENT AND DESIGN STAFF:** Mr. D. J. Nessan was the Resident Engineer at the project site. Mr. C. A. Powell was the Garrison Area Engineer. Mr. S. L. Price was Chief, Construction Div., Omaha District, and Mr. Charles L. Hipp was Chief, Engineering Division, Omaha District. Don Knight was Chief, F&M, Omaha District. Mr. L. J. Stutz, F&M, Omaha District and Mr. A. Koop, F&M, Omaha District were Project Engineer and Geologist, respectively.

CHAPTER 2. - FOUNDATION EXPLORATIONS

2.1 FOUNDATION EXPLORATIONS:

2.1.1 Investigations Prior to Construction - Including Testing: Preconstruction borings consisted of thirty-three drill holes at depths between 18 to 114 feet. Four initial borings were drilled for the right bank spillway location in the fall of 1959. Twenty-nine additional holes were drilled in 1963 along the embankment centerline, in the outlet works area, the alternative spillway location (left bank), and the right bank spillway location. Hole locations are shown on Plate 4. (Note: Holes on Plate 4 without a yearly prefix are holes drilled in 1959). Plates 5 thru 12 show subsurface conditions encountered in the bore holes.

In addition, borings for five piezometers and six lignite water pressure tests were drilled in 1963.

Drill holes 63-13, 63-19, and 63-26 thru 63-28, were drilled with a rotary drill which used a 5-3/8" double tube core barrel or Dennison barrel. The remainder of the borings were drilled by a churn drill with 4" or 6" drive barrels. Borings were drilled at varying depths into the Ludlow formation. Disturbed (jar) and moisture samples were taken from all borings at changes-of-material or 5-foot intervals. Undisturbed samples were taken from holes drilled by the rotary method. Standard penetration tests were not taken. Characteristics of the materials will be discussed under "Engineering Characteristics of Overburden and Bedrock."

2.1.2 Investigations During Construction: In 1966, 10 additional holes were drilled in the emergency spillway as general investigation holes along the centerline and for exploration to determine location of the spillway scour cutoff. Hole locations are indicated on plate 4. Strip logs of the spillway holes are shown on plates 7 and 10.

CHAPTER 3. - GEOLOGY

3.1 REGIONAL GEOLOGY: The Bowman-Haley Project lies within the unglaciated Missouri Plateau section of the Great Plains Physiographic Province. The history of this Province has been of long erosion which has resulted in residual buttes and mesas that rise 400-600 feet above the lower erosion surface. Rocks in the general project area are Paleocene continental deposits of the Ludlow formation. The Tongue River formation overlies the Ludlow at higher elevations on buttes and mesas. The overall regional dip is toward the north into the Williston basin at 10 to 20 feet per mile. The project is northeast of the Black Hills uplift area and directly east of the Cedar Creek Anticline.

3.2 SITE GEOLOGY: Plate 3 shows the geology at the site. Surface geology consists of the Ludlow formation which is thinly covered by residual soil. The Ludlow is approximately 184 feet thick and, at the site, extends from elevation 2836 to elevation 2656.

3.2.1 Physiography: The Project site consists of a rolling prairie with a dendritic drainage system which has developed on the unconsolidated sediments. The North Fork of the Grand River, Spring Creek, and their tributaries, commonly have incised meanders. Flood plains of streams are bordered by low terraces and cutoff meanders.

3.2.2 Description of Overburden: Overburden consists of thin (0-5 feet thick) residual soils which have developed on the Ludlow formation and alluvial valley deposits and consist mainly of fine sands and silty sands, along with minor amounts of lean clay that is underlain by gravelly sand, clayey gravel, and sandy gravel. A gravel terrace deposit (1-3 feet in thickness) was located beneath the left bank embankment. The gravel was removed by stripping operations.

3.2.3 Bedrock Stratigraphy: The Ludlow formation is composed of interbedded, lenticular mixtures of poorly indurated shales (classified as lean clays, sandy clays, fat clays), sandstones (classified as clayey sands, silty sands, calcareous sands), indurated sandstones (soft to hard) and lignites. Five lignites, designated as "A", "B", "C", "D", and "E" are present. The lignites serve as marker beds for correlation and as reference datum. The lignites and other bedrock units at the project are shown by profiles on plates 5 thru 12. The material above lignite "C" on the left bank is mainly stiff to very stiff sandy clay and dense clayey sands interbedded by dense, silty sands. Lignite "C" is 30 to 40 feet lower in the left bank area than the right bank. Material above lignite "C" on the right bank area consists of dense, clayey sand and stiff sandy clay. The material between lignites "C" and "A" is approximately 36 to 41 feet in thickness and consists of stiff to very stiff lean clays, sandy clays, and fat clays. Besides the lignites, the most distinct lithologic unit at the site is a green-gray dense clayey sand horizon which is between the "A" and "B" horizons. A thin (1 to 2 feet in thickness) discontinuous sandstone occurs

midway between the "A" and "B" lignites and, during the exploration phase of the project, served as an additional marker horizon.

3.2.4 Bedrock Structure, Jointing, Discontinuities: No evidence of faulting has been found in the immediate project area nor are there any discontinuities. Overall bedrock structure is best illustrated by the lignites which undulate gently over the project area but, locally, can be relatively level. No distinct bedding is apparent in the Ludlow nor are any joint patterns apparent in bedrock.

3.2.5 Bedrock Weathering: At the site, the Ludlow formation is weathered into colluvial and alluvial deposits consisting of varied mixtures of clays, sands and silts. Weathered bedrock is 5 feet or less in thickness on the abutment slopes and merges with alluvial deposits in the valley.

3.2.6 Leaching and/or Solution Activity: Neither solution nor leaching activity of the bedrock or overburden has been a problem at the project.

3.2.7 Ground Water: Ground water levels were taken in 17 of the 24 exploratory borings. Ground water levels, as encountered in the drill holes, are shown on plates 5 thru 12. Ground water was encountered in pervious floodplain deposits at approximately 5 to 10 feet above bedrock. Overall, the borings in the Ludlow formation indicated ground water levels at one or more horizons, but there did not appear to be any extensive lateral continuity of wet or saturated zones. This is very probably due to lateral changes in lithology within the Ludlow. Water was encountered in amounts which varied from moist to saturated in all lignites, but no single lignite was found to be water-bearing over an extensive area. The "A" lignite layer was water pressure tested but it did not appear that the lignite was sufficiently jointed or fractured to transmit any appreciable amount of water.

Water levels across the valley section were found to be uniform and ranged in elevation from 2713 to 2718 MSL. Water levels in the right abutment area reflect the topographic rise as ground water elevations rose from 2722.5 MSL near the valley floor to 2777.5 in the spillway area. The ground water level in the left abutment area also reflectd a topographic rise to the abutment. Top-of-ground water was found to be at elevation 2735 MSL for the left abutment area.

3.3 ENGINEERING CHARACTERISTICS OF OVERBURDEN MATERIALS:

3.3.1 Overburden Materials Classified As: Lean and sandy clay (CL); clayey sand (SC); silty sand (SM); and clayey and sandy silts (ML). Atterberg limits are given in Table 1, below.

TABLE 1
ATTERBERG LIMITS - OVERBURDEN MATERIALS

SOURCE	ATTERBERG LIMITS-RANGE	PREDOMINANT VALUE
Left Abutment Area (includes Borrow Area)	LL 26-96 PI 0-74	33-52 (CL, ML) 4-24
Left Valley Area	LL 25-94 PI 2-70	34-47 (CL) 14-28
Right Valley Area	LL 25-73 PI 1-43	28-41 (CL, ML) 7-22
Right Abutment Area-Embankment	LL 28-70 PI 4-45	39-57 (CL, ML) 19-35
Right Abutment Area-Spillway	LL 21-74 PI 0-39	29-41 (CL, ML) 4-20

3.3.2 Five series of direct shear tests were performed on remolded embankment and undisturbed foundation material. Remolded specimens were compacted to 95 percent of maximum density with water contents 2 percent above optimum. Adopted shear strength values for overburden and embankment materials are given below in Table 2. (Coh. is in T/sq. ft.). Results of direct shear tests are given on Plates 13 thru 15.

TABLE 2
SHEAR STRENGTH VALUES

Material	Unconsolidated Undrained (Q) Strength		Consolidated Undrained (R) Strength		Consolidated Drained (S) Strength	
	Tan ϕ	Coh.	Tan ϕ	Coh.	Tan ϕ	Coh.
Embankment	0.02	0.88	0.23	0.35	0.50	0
Overburden (Lean and Fat Clay)	0.32	0.60	0.20*	0.10*	0.45	0
Clayey Sand Between "A" and "B" Lignite	0.49	1.30	0.47	2.06	0.65	0

*The alluvial clay overburden's low R strength indicated low safety factors for stability. As construction progressed, overburden was removed as indicated in contract plans or as determined in the field.

3.3.3 Triaxial compression tests were performed on remolded embankment material and undisturbed samples of foundation material.

3.3.3.1 Two series of "Q" tests were performed on sandy clay embankment material remolded to 95% of maximum density and at optimum, and 2% above optimum, moisture contents. Shear strengths were: coh. = 1.12 T/sq. ft., and tan ϕ = 0.05; coh. = 0.88 T/sq. ft., and tan ϕ = 0.02.

3.3.3.2 One series of "R" tests on material remolded to 95% of maximum density at 2% above optimum moisture indicated a shear strength coh. = 0.35 T/sq. ft. and tan ϕ = 0.23.

3.4 ENGINEERING CHARACTERISTICS OF BEDROCK:

3.4.1 The Ludlow formation consists of interbedded lenses of lean-clays, sandy clays, fat clays, clayey sands and silty sands and soft-to-hard thin bedded calcareous sandstones, soft shales, lignites and carbonaceous, silty clays. Sands in the Ludlow formation are generally fine grained.

3.4.2 A series of direct shear tests were performed on undisturbed foundation material. Adopted shear strength values that were used for stability computations are given below in Table 3.

TABLE 3

Material	Unconsolidated Undrained (Q) Strength		Consolidated Undrained (R) Strength		Consolidated Drained (S) Strength	
	Tan ϕ	Coh.	Tan ϕ	Coh.	Tan ϕ	Coh.
Lean and Fat Clay (Ludlow)	0.40	1.30	0.38	1.80	0	0
Clayey Sand Between "A" and "B" Lignites (Ludlow)	0.49	1.30	0.47	2.00	0.65	0

Resulting strengths from four series of "Q" tests and four series of "R" tests on bedrock material were:

Type Test	Material	Cohesion T/sq. ft.	Tan ϕ
"Q"	Clayey Sand (Ludlow)	1.3	0.49
"Q"	Lean Clay (Ludlow)	0.7	0.56
"Q"	Lean Clay (Ludlow)	2.9	0.39
"R"	Fat Clay (Ludlow)	1.8	0.38

The result of tests on the Ludlow formation are shown on Plates 13 and 14.

3.4.3 Direct shear tests on clayey sands of the Ludlow formation show no cohesion and have a high friction angle (Tan ϕ = 0.85). Fat clays have some cohesion (0.15 TSF) and a lower friction angle (Tan ϕ = 0.45) than the sands. Consolidated, drained, design strengths were taken from these tests.

3.4.3.1 For the unconfined compression tests, the Ludlow sands have an average unconfined strength of 1.56 TSF. The test results are very consistant for the sands. Ludlow sands all failed at approximately 2% axial strain.

3.4.3.2 Two types of lean clay were tested for the "Q" triaxial tests. Tangents of $\emptyset$ were 0.56 and 0.39 for the samples and C equaled 0.7 TSF and 2.9 TSF respectively. Foundation design values were a compromise between the two clay test values. "Q" tests on the Ludlow clayey sand gave a tan $\emptyset$ = 0.49 and C = 1.3 TSF. These values were used for foundation designs.

3.4.3.3 "R" test results from Plate 14 indicate that one set was unsuccessful on Ludlow clays. The other set gave peak strength at values of, Tan $\emptyset$ = 0.38. Samples in the second set all failed at 4 to 5% axial strains. Ultimate strengths were: For the clay, Tan $\emptyset$ = 0.38; for the sand, Tan $\emptyset$ = 0.47 and C = 2.0 TSF. The ultimate strength values were used for design.

3.5 UNUSUAL OR UNANTICIPATED GEOLOGIC CONDITIONS ENCOUNTERED DURING CONSTRUCTION:

3.5.1 In June 1967, the Contractor, Brezina Construction Company, filed a changed conditions claim related to rock quantities, bedding, and lithology encountered during excavation of the spillway.

3.5.1.1 While excavating the spillway, the Contractor claimed that he encountered extensive areas of unanticipated limestone boulders which extended to depths of 10-12 feet - "like eggs in a nest." The total claim was for $700,000. The Government's position was that contract drawings accurately portrayed subsurface conditions. The Contractor agreed that he expected to encounter rock; however, he could not anticipate the "massiveness" or position of the rock.

3.5.1.2 The Government allowed the Contractor to utilize the rock boulders encountered in the spillway for rip-rap. The Contractor claimed that excavation of the spillway rock for rip-rap stockpiling caused him delays in embankment closure and excavation of the outlet works. To this contention, the Government maintained that it was the locations at which the Contractor chose to stockpile the spillway rock which caused construction delays-rock was stockpiled in such a manner that it interfered with the movement of equipment and improper equipment was used for excavation.

3.5.1.3 In August 1967, the District Engineer determined that the Contractor had encountered a changed condition, and had a claim.

3.5.1.4 Original exploration for the spillway consisted of four drill holes (DH-1 - DH-4) drilled in 1959 and two drilled in 1963 (DH63-16 and 63-9). Hole locations are shown on Plate 4, and subsurface conditions encountered by the bore holes are shown on Plates 5, 6, 8 and 10. The claim was not related to the extent of sufficiency of exploration, but to "rock" as interpreted by the Contractor from the drill hole logs.

3.5.2 A unique foundation condition for the Bowman-Haley Project exists in the form of lignites which underlay the reservoir and embankment. Bore hole profiles which indicate lignite horizons are shown on Plates 5 thru 12.

3.5.2.1 Seepage under the embankment has occurred along Lignite "A". Seepage surfaces along the sides of the stilling basin and is directly related to reservoir levels. No structures have been damaged by the seepage nor is it presently considered a serious problem for the project structures. Seepage along Lignite "A" will be further discussed later in this report under "Foundation Instrumentation," "Possible Future Problems," and Chapter 4. The relationship of Lignite "A" to the embankment is shown on plates 25, 26 and 27.

CHAPTER 4. - SPECIAL DESIGN CONSIDERATIONS

4.1 EMBANKMENT FOUNDATION CUTOFF TRENCH:

4.1.1 Approximately an 80 foot (width) of low "R" shear strength alluvium clay was removed from the foundation from Station 37+00 to Station 42+50 for foundation stability. Underseepage control is provided in the valley section by a cutoff trench from Station 29+00 to Station 59+00. This portion of the trench is through alluvial sands and gravels and extends to the clayey sand horizon which underlies the "A" lignite (Plates 5, 6, and 9). The clayey sand is considered impervious with 33% to 44% of the material passing the #200 sieve and horizontal and vertical coefficients of permeability of 5.5 x 10-7 and 5.8 x 10-7 cm/sec. respectively. The trench has a 25 foot bottom width in the valley section, 1:1 side slopes (Plate 19), and narrows to 5'-8' widths on abutment slopes. Trench backfill is impervious material that consists of lean clays, clayey silts, sandy clays or silts.

The bottom of flat or gently sloping portions of the excavated trench was scarified to a depth of six inches and one initial lift of impervious material was compacted on the trench bottom with sheeps foot tamping rollers and power and hand tampers. The impervious fill was then brought up in 4"-6" lifts.

4.1.2 A shallower (5 to 15 feet in depth) portion of the cutoff trench extends from Station 59+00 to Station 70+00. This portion of the trench extends through more gravelly and sandy material above the "C" and "E" lignites, but does not penetrate any of the lignites.

4.1.3 From Station 29+00 to Station 25+80, the trench extends upslope at a depth of five feet. The trench intercepts the "C" lignite at Station 27+50. From Station 25+80 to Station 27+50, the trench bottoms in silty sands and sandy clays. From Station 27+50 to Station 29+00, the trench generally bottoms in lean and fat clays.

4.1.3.1 For the portion of the trench between Station 29+00 and Station 25+80, loose material was removed from the existing slope and the trench excavated in notches up and down slope. Fill was placed and rolled to bind with natural material.

A considerable amount of borrow used for the impervious fill was very dry and required watering, discing, and blading with the result that lifts were restricted to 4"-6" in thickness to allow adequate mixing by discs and blades.

4.1.4 Laboratory and field compaction tests for the cutoff trench impervious fill are given below on Table 4.

TABLE 4
BONHAM-HALEY DAM
EMBANKMENT CUTOFF TRENCH
SUMMARY OF COMPACTION TEST RESULTS

DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	LAB DATA MAX. DENSITY	LAB DATA OPT. M	FIELD DATA DRY DENSITY	FIELD DATA Z M	FIELD DATA Z COMP.	CLASS
Oct 9, 1965	48	38+25	Centerline	2714	Sheeps Foot	6	Balloon	103.4	20.5	98.5	22.2	95.5	CL, Sdy, Si
Oct 13, 1965	57	36+00	Centerline	2709	Sheeps Foot	6	Balloon	103.4	20.5	100.6	22.6	97.3	CL, Sdy, Si
Oct 13, 1965	59	34+75	Centerline	2712	Sheeps Foot	-	Balloon	103.4	20.5	92.0	24.3	94.8	CL, Sdy, Si
Oct 14, 1965	62	34+25	Centerline	2718	Sheeps Foot	6+	Balloon	103.4	20.5	102.3	23.3	98.9	CL, Sdy, Si
Oct 14, 1965	63	32+75	Centerline	2720	Sheeps Foot	6+	Balloon	103.4	20.5	102.3	23.0	98.9	CL, Sdy, Si
Oct 14, 1965	64	40+25	8' Rt. Center	2708	Sheeps Foot	6	Sand	103.4	20.5	98.0	22.9	94.8	CL, Sdy, Si
Oct 14, 1965	65	41+50	Center Line	2707	Sheeps Foot	6	Sand	103.4	20.5	102.1	20.9	98.7	CL, Sdy, Si
Oct 14, 1965	66	39+00	5' Lt Center	2714	Sheeps Foot	6	Sand	103.4	20.5	98.1	20.7	94.9	CL, Sdy, Si
Oct 15, 1965	67	40+00	Center Line	2713	Sheeps Foot	6	Balloon	103.4	20.5	99.6	18.5	96.3	CL, Sdy, Si
Oct 15, 1965	68	38+10	Centerline	2716	Sheeps Foot	6+	Balloon	103.4	20.5	103.1	18.3	99.7	CL, Sdy, Si
Oct 15, 1965	69	52+50	6' Rt. Center	2712	Sheeps Foot	6	Sand	103.7	12.5	103.4	18.5	99.7	CL, Sdy, Si
Oct 15, 1965	70	56+00	8' Lt. Center	2716	Sheeps Foot	6	Sand	103.7	12.5	101.0	19.0	97.3	CL, Sdy, Si
Oct 16, 1965	71	37+10	15' Lt. Center	2719	Sheeps Foot	6+	Sand	103.4	20.5	103.3	16.5	99.9	CL, Sdy, Si
Oct 16, 1965	72	56+60	5' Lt. Center	2710	Sheeps Foot	6	Sand	104.4	19.8	104.1	20.9	99.7	CL, Sdy, Si
Oct 16, 1965	74	31+40	12' Rt. Center	2721	Sheeps Foot	6	Sand	104.4	19.8	99.2	20.8	95.9	CL, Sdy, Si
Oct 17, 1965	75	49+50	3' Rt. Center	2712	Sheeps Foot	6+	Sand	103.7	12.5	107.6	18.3	103.8	CL, Sdy, Si
Oct 17, 1965	76	56+50	10' Lt. Center	2720	Sheeps Foot	6+	Balloon	103.7	12.5	107.2	18.1	103.5	CL, Sdy, Si
Oct 17, 1965	77	47+80	Centerline	2708	Sheeps Foot	6	Sand	103.7	12.5	104.2	20.0	100.5	CL, Sdy, Si
Oct 18, 1965	80	30+50	Centerline	2727	Sheeps Foot	6	Balloon	103.7	12.5	104.1	12.4	93.9	SM
Oct 18, 1965	81	54+00	Centerline	2713	Sheeps Foot	6+	Balloon	103.7	12.5	104.7	18.9	101.0	CL, Sdy, Si
Oct 18, 1965	84	29+50	15' Lt. Center	2731	Sheeps Foot	6	Balloon	103.4	20.5	102.2	16.9	98.8	CL, Sdy, Si
Oct 18, 1965	85	31+20	15' Lt. Center	2728	Sheeps Foot	6	Sand	103.4	20.5	100.7	17.8	97.4	CL, Sdy, Si
Oct 18, 1965	86	35+00	10' Lt. Center	2727	Sheeps Foot	6	Sand	103.4	20.5	105.9	18.1	102.4	CL, Sdy, Si
Oct 18, 1965	87	33+10	20' Rt. Center	2729	Sheeps Foot	6	Balloon	103.4	20.5	101.2	18.3	97.9	CL, Sdy, Si
Oct 19, 1965	88	30+00	20' Rt. Center	2734	Sheeps Foot	6	Balloon	103.4	20.5	100.8	19.9	97.5	CL, Sdy, Si
Oct 20, 1965	95	29+40	10' Rt. Center	2740	Sheeps Foot	6	Balloon	110.9	16.6	105.3	13.9	95.0	SM
Oct 20, 1965	96	46+00	Centerline	2717	Sheeps Foot	6	Balloon	106.9	19.6	96.4	23.8	90.2	CL
Oct 20, 1965	97	32+50	35' Rt. Center	2725	Sheeps Foot	6	Balloon	103.4	20.5	101.3	15.9	98.0	CL, Sdy, Si

TABLE 4 (Cont'd)
BONHAM-HALEY DAM
EMBANKMENT CUTOFF TRENCH
SUMMARY OF COMPACTION TEST RESULTS

DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	LAB DATA MAX. DENSITY	LAB DATA OPT. M	FIELD DATA DRY DENSITY	FIELD DATA Z M	FIELD DATA Z COMP.	CLASS
Oct 20, 1965	98	47+90	10' Rt. Center	2715	Sheeps Foot	6	Balloon	106.9	19.6	96.6	23.2	90.4	CL
Oct 20, 1965	99	34+10	10' Lt. Center	2718	Sheeps Foot	6	Balloon	103.4	20.5	105.5	17.7	102.0	CL, Sdy, Si
Oct 20, 1965	100	31+20	35' Rt. Center	2735	Sheeps Foot	6	Balloon	103.4	20.5	104.1	14.8	100.7	CL, Sdy, Si
Oct 21, 1965	102	50+00	10' Lt. Center	2719	Sheeps Foot	6	Proctor	103.4	20.5	100.0	25.4	93.5	CL, Sdy, Si
Oct 21, 1965	103	42+45	15' Rt. Center	2713	Sheeps Foot	6	Balloon	103.4	20.5	99.0	12.8	95.7	CL, Sdy, Si
Oct 21, 1965	104	36+75	80' Rt. Center	2727	Sheeps Foot	6	Balloon	103.4	20.5	107.2	14.5	103.7	CL, Sdy, Si
Oct 21, 1965	105	47+85	20' Rt. Center	2719	Sheeps Foot	6	Balloon	106.9	19.6	99.3	23.6	92.9	CL, Sdy, Si
Oct 22, 1965	108	55+83	10' Lt. Center	2721	Sheeps Foot	6	Balloon	106.9	19.6	110.1	16.7	103.0	CL
Oct 23, 1965	112	38+25	25' Lt. Center	2728	Sheeps Foot	6+	Balloon	106.9	19.6	111.0	12.7	107.4	CL, Sdy, Si
Oct 23, 1965	114	41+00	Centerline	2716	Sheeps Foot	6	Balloon	110.9	16.6	108.8	15.4	98.1	SM
Oct 23, 1965	115	39+00	170' Rt. Center	2728	Sheeps Foot	6	Balloon	103.4	20.5	103.3	12.3	99.9	CL, Sdy, Si
Oct 26, 1965	119	42+50	20' Rt. Center	2716	Sheeps Foot	6+	Balloon	103.4	20.5	102.7	19.3	99.3	CL, Sdy, Si
Oct 26, 1965	121	51+60	15' Lt. Center	2734	Sheeps Foot	6	Balloon	106.9	19.6	101.8	22.0	95.2	CL
Oct 26, 1965	122	41+90	5' Rt. Center	2723	Sheeps Foot	6+	Balloon	103.4	20.5	101.0	15.6	97.7	CL, Sdy, Si
Oct 26, 1965	123	58+80	4' Rt. Center	2720	Sheeps Foot	6	Balloon	106.9	19.6	102.9	22.9	96.3	CL
Oct 27, 1965	126	58+25	15' Rt. Center	2728	Sheeps Foot	6	Balloon	106.9	19.6	88.8	25.9	83.3	CL
Oct 28, 1965	128	42+40	15' Lt. Center	2728	Sheeps Foot	6	Balloon	106.9	19.6	100.6	16.7	94.1	CL
Oct 29, 1965	131	58+00	30' Lt. Center	2735	Sheeps Foot	6+	Balloon	103.4	20.5	94.0	24.7	90.1	CL, Sdy, Si
Oct 29, 1965	133A	58+90	25' Lt. Center	2740	Sheeps Foot	6+	Balloon	106.9	19.6	101.8	21.0	95.2	CL
Oct 29, 1965	134A	56+85	20' Rt. Center	2735	Sheeps Foot	6+	Balloon	106.9	19.6	100.5	23.7	94.0	CL
Oct 30, 1965	136	50+00	10' Lt. Center	2722	Sheeps Foot	6	Balloon	106.9	19.6	100.6	21.0	94.1	CL
Nov 1, 1965	137	53+75	25' Lt. Center	2727	Sheeps Foot	6+	Balloon	106.9	19.6	98.3	22.7	92.0	CL
Nov 2, 1965	139	53+00	30' Lt. Center	2727	Sheeps Foot	6	Balloon	106.9	19.6	99.1	25.3	92.7	CL
Nov 2, 1965	140	36+50	35' Lt. Center	2732	Sheeps Foot	6+	Balloon	103.4	20.5	109.7	15.5	106.1	CL, Sdy, Si
Nov 2, 1965	141	48+95	15' Lt. Center	2725	Sheeps Foot	6+	Balloon	103.4	20.5	105.2	14.9	101.7	CL, Sdy, Si
Nov 3, 1965	147	49+70	30' Lt. Center	2726	Sheeps Foot	6+	Balloon	106.9	19.6	104.0	19.3	97.3	CL
Nov 3, 1965	149	36+30	20' Rt. Center	2732	Sheeps Foot	6	Balloon	113.1	15.6	104.8	17.3	92.5	CL, Sdy

TABLE 4 (Cont'd)
[illegible]
[illegible]
SUMMARY OF COMPACTION TEST RESULTS

DATE TESTED	TEST NUMBER	STATION	RANGE	ELEVATION	TYPE OF ROLLER	NO. OF PASSES	TYPE OF DENSITY TEST	LAB DATA MAX. DENSITY	LAB DATA OPT. M	FIELD DATA DRY DENSITY	FIELD DATA Z M	FIELD DATA Z COMP.	CLASS
Nov 4, 1965	150	46+75	35' Lt. Center	2728	Sheeps Foot	6	Balloon	113.1	15.6	104.4	18.5	92.3	CL, Sdy
Nov 9, 1965	165	54+50	30' Rt. Center	2734	Sheeps Foot	6+	Balloon	106.9	19.6	105.8	21.5	99.0	CL
Nov 9, 1965	167	54+00	10" Rt. Center	2730	Sheeps Foot	6+	Balloon	102.7	17.5	108.0	16.2	105.2	ML, Sdy
Nov 10, 1965	170	51+75	Centerline	2729	Sheeps Foot	3	Balloon	102.7	17.5	96.0	14.0	93.2	ML, Sdy
Nov 10, 1965	171	46+95	35' Rt. Center	2725	Sheeps Foot	6+	Balloon	103.4	20.5	102.2	21.1	99.0	CL, Sdy, Si
Nov 11, 1965	174	46+50	45' Rt. Center	2729	Sheeps Foot	6+	Balloon	103.4	20.5	102.7	17.6	99.2	CL, Sdy, Si
Nov 11, 1965	175	48+50	Centerline	2730	Sheeps Foot	6+	Balloon	102.7	17.5	116.1	15.8	113.0	ML, Sdy

4.2 PERMEABILITY OF LIGNITES THAT UNDERLIE THE EMBANKMENT:

4.2.1 It was recognized early in the project that lignites represented potential seepage zones. To verify whether or not a seepage problem along the lignites could occur, a representative lignite (the "A" lignite) was pressure tested by water.

4.2.1.1 The "A" lignite was selected for testing because it was considered to be representative of all the lignites and was thick enough (approx. 3 feet) to provide a satisfactory test. In preparation for the water pressure tests, a series of 5 piezometers were installed on the right abutment - two upstream and two downstream - from the proposed embankment centerline and one on the centerline. The holes were drilled to the bottom of Lignite "A". Prior to setting the well points, grout was tremied to the bottom of each hole, forming a plug to seal off the underlying beds. The well points were then installed within the vertical limits of Lignite "A", with a bentonite plug at the top of the lignite to seal off the overlying beds. Upon completion of the piezometer installations, the water levels in Lignite "A", when present, were measured prior to running the pressure tests. Three separate water pressure test holes were drilled, each to the bottom of Lignite "A". I- preparing the test holes, grout was tremied to the bottom to seal off the underlying beds. In testing each hole, a single packer assembly was used to seal off the overlying beds. The lignite bed, isolated from the top and bottom, was then subjected to a water pressure gage reading at the surface equal to 1 pound of pressure for each foot of depth in the hole. This water pressure, plus the weight of the column of water in the drill pipe, was the maximum applied to the lignite unit. During the test period, records were kept of the applied pressure and the water take per unit of time, and also water levels in the piezometers, if present, were recorded at regular intervals. Prior to running the series of tests on the right bank, a similar testing program was proposed for the left abutment, but in light of the negligible water take in Lignite "A" on the right bank, the left bank testing program was modified. Piezometers were not installed on the left bank; however, 3 drill holes were pressure tested. The tests on Lignite "A" confirmed the results obtained from the right bank in that Lignite "A" did not take appreciable amounts of water. From the results of the tests it appeared that Lignite "A", at the six locations, was not jointed or fractured sufficiently to pass any appreciable amount of water.

4.2.1.2 Water pressure tests were performed on the "A" lignite vein in each abutment to determine the degree of cracking, apparent permeability, and possible need for grouting. The thickness of the "A" lignite as determined from the six pressure test holes varied from 2.5 to 2.8 feet. The lignite beds were the only layers in the abutments with a water bearing potential as the remaining foundation material below the elevation of the conservation pool was indicated to be impervious. Pressure test hole T-4 was the only hole that showed even a nominal water take 1.28 - gpm with a gage pressure at the ground surface of 24 psi. This pressure, plus the column of water in the hole, would result in a water head at the elevation of the lignite layer of 80 feet. The other five holes had an average water take of 0.25 gpm under an average gage pressure of 35 psi, equal to a water head of over 100 feet. The

piezometers installed in the "A" lignite did not show any change in water level during the water pressure tests. The tests indicated that even under a head of water twice as high as would result with the pool at conservation level, the lignite would not pass an appreciable amount of water, and that grouting of the lignite was not required. The results were consistent with experience elsewhere with thin lignites of the Fort Union group - such as the 2-foot-thick abutment lignites at Garrison Dam where very few holes would accept grout. Table 5 below summarizes Pressure Test results. Test hole and piezometer locations are shown on Plate 4.

TABLE 5
WATER PRESSURE TEST RESULTS
BOWMAN-HALEY DAM
September 1963

(a) "A" Lignite Test, Hole T-1.

Gage Pressure	Time	Take (Total)	Take (gpm)
10 psi	--	---	---
35 psi	30 min.	3.4 gal.	0.11 gpm
40 psi	30 min.	2.9 gal.	0.10 gpm
45 psi	30 min.	5.6 gal.	0.19 gpm
50 psi	30 min.	7.5 gal.	0.25 gpm

Piezometer reactions: Test Hole T-1.
P-1, 500' upstream, 1 foot rise
P-4, 150' downstream, 1 foot rise

(b) "A" Lignite Test, Hole T-2A

Gage Pressure	Time	Take (Total)	Take (gpm)
32	240 min.	24.1 gal.	0.10 gpm

Piezometer reactions: Test Hole, T-2A.
Piezometers 1, 2, 3, 4, 5 - no reactions.

(c) "A" Lignite Test Holes T-3, T-4, T-5.

Gage Pressure	Time	Take (Total)	Take (gpm)
		Hole T-3	
28	120 min.	20.4 gal.	0.16 gpm
		Hole T-4	
24	120 min.	154.3 gal.	1.28 gpm
		Hole T-5	
32	120 min.	2.7 gal.	0.02 gpm

No piezometer reactions for Holes T-3, T-4, T-5 were given in the original field notes.

4.3 SPILLWAY FUSE PLUG FOUNDATION:

4.3.1 A fuse plug was constructed in the spillway. The plug is located at spillway Station 27+50 (Plate 17), and is designed to store 90 percent of the standard project flood before failing under floods of greater magnitude.

4.3.2 Drill Hole #DH-1, as shown on Plates 4 and 16, indicates a predominance of sandy clay material for the fuse plug foundation. Two 12-inch by 72-foot corrugated metal pipes are located at the base of the fuse plug at the flow line elevation of the spillway (Plate 16).

4.3.3 The original surface beneath the fuse plug was cleared and stripped to a depth of 6 inches and a 2-foot layer of compacted impervious fill was placed on the cleared foundation. Pervious fill was then placed on the impervious base of the fuse plug.

4.3.4 The spillway fuse plug is designed to store the standard project flood but to fail whenever overtopped by floods of greater magnitudes. It was felt that seepage under the fuse plug would not present a problem due to the base width of the plug and the relatively low potential head that could be expected against the plug. Plate 16 shows the fuse plug profile.

4.4 SPILLWAY SCOUR CUTOFF: As shown on Plate 16 and 17, a soil cement scour trench was constructed near the lower end of the spillway channel. The scour cutoff bottoms between the "C" and "D" lignites in the spillway and relies on the lignites to provide some degree of erosion control if needed. The scour cutoff trench extends approximately 12 feet below the spillway floor at Station 23+00. Plate 16 shows details of the spillway scour cutoff.

4.4.1 Material placed in the scour cutoff consisted of a combination of soil (mineral aggregate), Portland cement, and water. The soil (mineral aggregate) was obtained from local alluvial deposits and met the following gradation requirements:

Sieve Size	% Passing (Weight)
3-inch	100
#4	50-75
#40	25-50
#200	5-15

Blending sands were added when necessary to meet gradation requirements. Mixing of the soil, cement, and water was accomplished by an in-place mixing plant.

4.4.2 The cement content of the soil-cement mix ranged between a minimum of 8% to a maximum of 12%. The amount of water in the mix was restricted on the basis of over dry weight such that, at compaction, the material was at, or no more than 2% above, optimum moisture as specified by AASHO Standard T 134-57. Haul times were restricted to 45 minutes maximum.

4.4.3 Soil-cement was placed in the trench in 6" layers and initially compacted with tamping rollers. Final compaction was by rubber-tired rollers. Compaction was to 95% of maximum density. Time between placing the 6" layers and complete compaction did not exceed 1-1/2 hours.

Bonding surfaces between the 6" layers were kept moist until the next layer of the mix was placed-either vertically or laterally. If time exceeded 4 hours between bonding layers the bonding surface was cleaned by wire brooms before placing the next layer.

CHAPTER 5. - EXCAVATION PROCEDURES FOR COMPONENT PARTS

5.1 EXCAVATION GRADES: AS-DESIGNED AND AS-BUILT: The original onsite field documentation of excavation cuts are no longer available. It is assumed that grades were excavated to profiles shown on specification drawings. It is realized that the bottom of the embankment cutoff trench probably varies slightly from the outline given on Plates 6 and 9 since the depth of excavation for the trench varied with the elevation of the "A" lignite and the "A" lignite undulates across the embankment area. The cutoff trench's bottom is below the "A" lignite.

5.2 DEWATERING:

5.2.1 As shown by photos 2 and 3 and drill holes 63-12, 63-4, 63-11, 63-3, and 63-10 (Plates 5 and 6), it was necessary to dewater the embankment cutoff trench; also, as shown by water levels for drill hole 63-18, it would have been necessary to dewater portions of the excavation for the outlet works. Details of the dewatering process are no longer available; however, photographs 2 and 3 give an indication of the general method used for the embankment cutoff trench.

5.2.2 It appears as though water levels were lowered by pumping while excavation below the "A" lignite was accomplished by bulldozers which pushed the excavated material into the ponded water. The water-earth mixture was removed by dragline bucket. Impervious fill was then placed and compacted by rollers.

5.3 OVERBURDEN EXCAVATION: Overburden was excavated by traditional bulldozer and scraper methods (photo 27). No special supporting methods were needed. Excavated overburden was used as fill for the project.

5.4 ROCK EXCAVATION: Excavation methods of the bedrock (Ludlow formation) were similar to methods used for the overburden. No drilling and blasting program was used.

5.5 SPILLWAY EXCAVATION: Spillway excavation was by conventional bulldozer and scraper methods. In addition, a power shovel was used to excavate the layer of concretionary rock encountered during spillway excavation (photo 24).

5.6 FOUNDATION PREPARATION (INCLUDES PROTECTION OF WEATHER SENSITIVE MATERIALS): Structure foundations were excavated to neat lines as shown on drawings after all unsuitable material was stripped from the surface. Prior to placing fill on flat or gently sloped areas, the foundation was scarified to a depth of 6 inches. The surface was then compacted. On steeper slopes, the slope was notched through any dried material to allow rollers to bond the fill to the slope material. Prior to placing fill, all foundation surfaces were inspected and approved by the Government. No fill was placed on any surface that was frozen or had standing water or was slushy or slippery. Work completion schedules were such that no critical surfaces were exposed during the winter months.

5.7 **SAFETY:** No special safety requirements were necessary to protect against slides or rock falls.

CHAPTER 6. - TUNNELS, SHAFTS, AND UNDERGROUND STRUCTURES

6.1 INTAKE CONDUIT: The outlet works are located in the left abutment. The excavation for the intake structure and conduit extend through the overburden and a lean clay-clayey sand horizon of the Ludlow formation (Plate 7). The bottom of the intake structure is located below the "A" lignite, and the structures are founded in the clayey sand layer between the "A" and "B" lignite. Details of the outlet works conduit are shown on Plate 22.

6.1.1 The conduit is 10 feet in diameter and consists of 14 cast-in-place monoliths that extend 341 feet between the intake structure and the stilling basin. Concrete collars were placed between all monoliths. The conduit was constructed through two contracts. The first contract involved placing 12 monoliths and the construction was completed by a second contract which placed the two remaining monoliths (those connecting to the intake structure and stilling basin). Photos 21 and 22 show methods used for casting in-place conduit inverts.

6.1.2 Excavation for the conduit was by conventional excavation methods. The conduit was cast in-place, and no unusual or unique foundation conditions were encountered during construction. The conduit foundation is the only underground structure at the project. Dewatering was necessary for construction portions of the conduit (Photo 11). Dewatering methods have been discussed in Chapter 5. Emplacement of the conduit was by the cut-and-cover method.

CHAPTER 7 - CHARACTER OF FOUNDATION

7.1 FOUNDATION SURFACE: The soil and rock units which form the foundation materials of the dam, after excavation of the cutoff trench, are shown on Plates 5 and 6. The plates indicate that generally from Station 25+00 to Station 55+00 foundation materials are mostly classified as SC. From Station 55+00 on the foundation materials are classified as CL.

7.2 Engineering characteristics of foundation soil and rock have previously been discussed under "Engineering Characteristics of overburden Material" and "Engineering Characteristics of Bedrock Material."

7.3 WATER:

7.3.1 Natural water levels at the project are shown on Plates 5 through 12. As indicated, water levels were generally below the base of the intake structure but above the bottom of portions of the cutoff trench. Portions of the cutoff trench were dewatered; however, original records with details of the dewatering program are not available.

7.4 SPECIAL OR UNUSUAL CONDITIONS: The dam is underlain by several lignite seams and seepage does occur along lignite "A." Seepage along the lignite is discussed later in this report under "Foundation Instrumentation." Water pressure tests of the lignite are discussed in paragraph 4.2.1.2.

CHAPTER 8. - FOUNDATION INSTRUMENTATION

8.1 GENERAL: Foundation instrumentation consists of seven (7) open tube piezometers, eleven (11) crest movement markers, thirty (30) conduit markers, six (6) stilling basin markers, and eight (8) intake markers. In addition, four lignite drains are used to monitor a seepage area on the left bank of the outlet channel near the stilling basin. Location of the instruments are shown on Plates 23 and 24.

8.2 PIEZOMETERS: Seven piezometers were installed in the left abutment in 1969 to monitor the piezometric gradient in the left abutment along a line of seepage through lignites. Piezometer observations are shown on Plate 23. Piezometer readings generally respond to pool fluctuations (Plates 25 through 27) and have decreased through time. This could indicate that there has been a buildup of silt along the upstream toe.

8.2.1 Seepage Through Lignites: In August 1968 (Periodic Inspection No. 1), seepage was observed to be emerging adjacent to the stilling basin at approximately elevation 2720. At the time the pool was at elevation 2749. The seepage was in or at the top of the "A" lignite layer. Several other seeps were observed at the same elevation further downstream from the stilling basin (Plate 24). Seepage was limited to the left abutment side of the outlet channel. Seepage water was clear with no evidence of piping. Seepage flow observations are shown on Plate 24A. The plate shows flow observations as indicated by four drains that had been installed earlier to monitor the seepage. In September 1982, the four older drains were replaced.

8.2.2 Overall seepage through the "A" lignite is sufficient to saturate the slope on the side of the stilling basin but is not considered dangerous to the abutment.

8.2.3 Crest Movement Markers: The location and plots of the crest movement markers are shown on Plates 28 and 29. The settlement plots show settlement at a fairly uniform rate except for marker CM-7 which has settled at a slower rate. There is slight nonuniform settlement in the area of the conduit that is not considered critical but is monitored. Maximum settlement has occurred in the closure area at Station 45+00 (CM-5) with 0.223 feet of total settlement. Crest markers indicate only minor horizontal movement and most of this is in the closure area.

8.3 CONDUIT, STILLING BASIN, AND INTAKE MARKERS: Vertical movement surveys for the structures are shown on Plate 30. Survey data indicates that only minor movement has occurred. It should be noted that the 1975 reading at Point C-13 and the 1981 reading at Point SB-5 are survey errors.

8.4 AUTOMATIC PIEZOMETER MONITORING SYSTEM: Due to the project's isolation and the fact that no employees of the Corps are stationed near the dam, a satellite monitoring system is currently being implemented to observe water

levels in six of the seven existing piezometers at the dam. Piezometer locations are shown on Plate 33 and an installation diagram is shown on Plate 34. Bell and Howell pressure transducers are being placed in the piezometers and every 4 hours water level readings will be relayed via the National Environmental Satellite Service to a U.S. Bureau of Reclamation station at Boise, Idaho. The data will be forwarded to the Corps computer in Portland, Oregon, where the information will be stored. Omaha District will receive the water levels daily through a telephone hookup. Specifications for the transducers are shown on Plate 35.

The system is justified by dam safety requirements. On several occasions in the past, the public has called the District Office with what they (the public) thought were safety problems. Although the reports were false, they were difficult to investigate in a timely matter. The satellite system will permit a timely determination as to whether or not a safety problem exists when similar reports are received from the public in the future. It is estimated that the automatic piezometer monitoring system will be operational by the end of 1985.

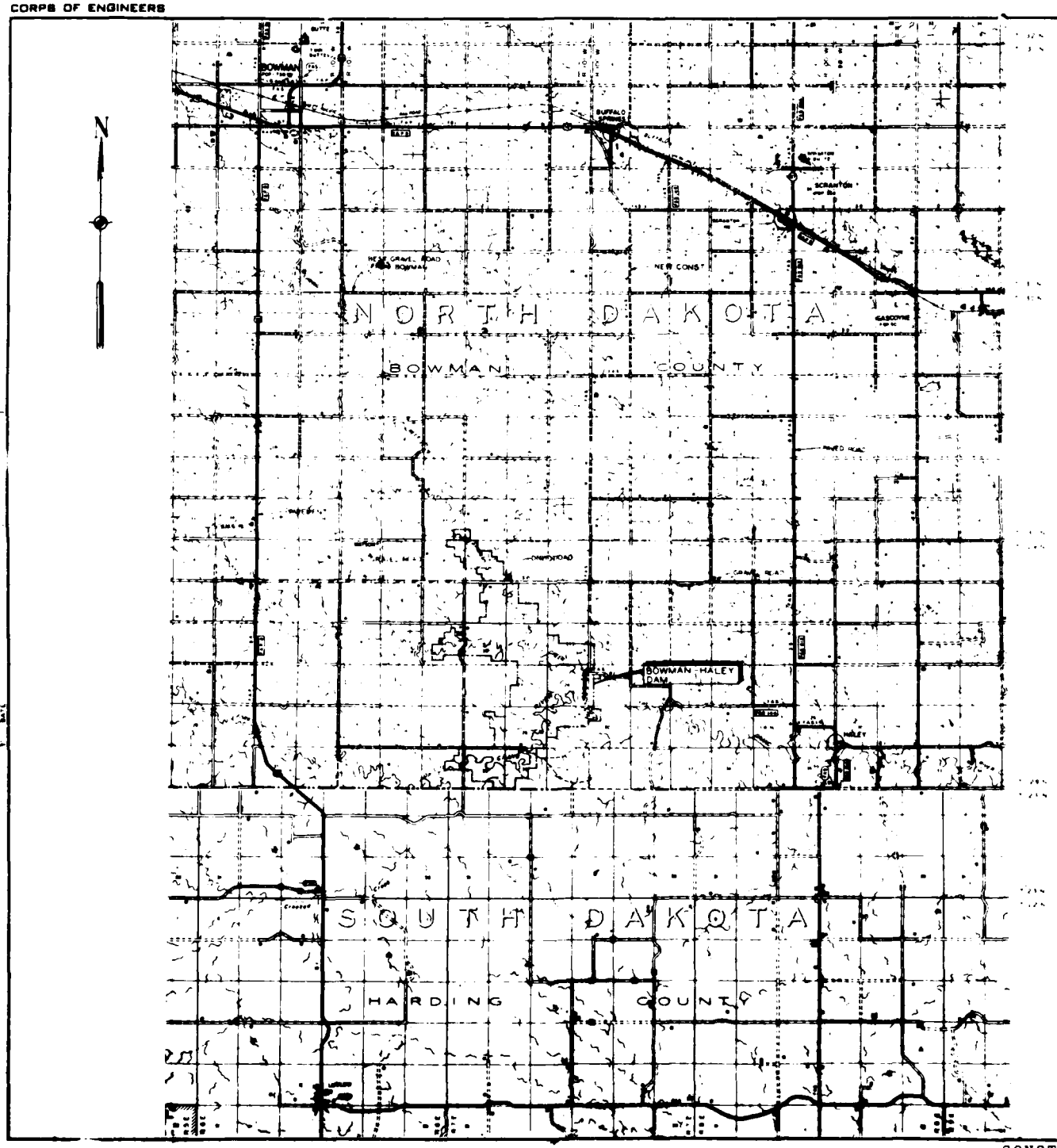
CHAPTER 9. - POSSIBLE FUTURE PROBLEMS

9.1 CONDUIT LEAKAGE: In June 1981, a slow oozing leak was discovered at the conduit monolith joint 9-10 which is approximately 50 feet upstream from the centerline of the dam. There was a three (3) inch deep layer of soil in the conduit that extended approximately 12 feet downstream from the joint and 5 feet upstream from the joint. Holes were drilled through the conduit to determine the existence of voids between the conduit and embankment material. No voids were found. Fill and water were found immediately behind the conduit in all the holes. Sieve analysis was run on the embankment soils and soil found inside the conduit. Embankment soil was a fat clay with 84 percent passing the No. 200. Soil found inside the conduit was silty with 28-34 percent passing the No. 200 sieve. Since no voids were found behind the conduit, it was concluded that embankment material was not piping through the conduit joint. It is possible that the sand was deposited in the wet area by wind passing through the conduit. Seepage which produces the moist area in the conduit is not presently considered critical but is closely monitored.

9.2 "A" LIGNITE: Underseepage through the "A" lignite is another potential future problem which is not currently critical but is monitored closely.

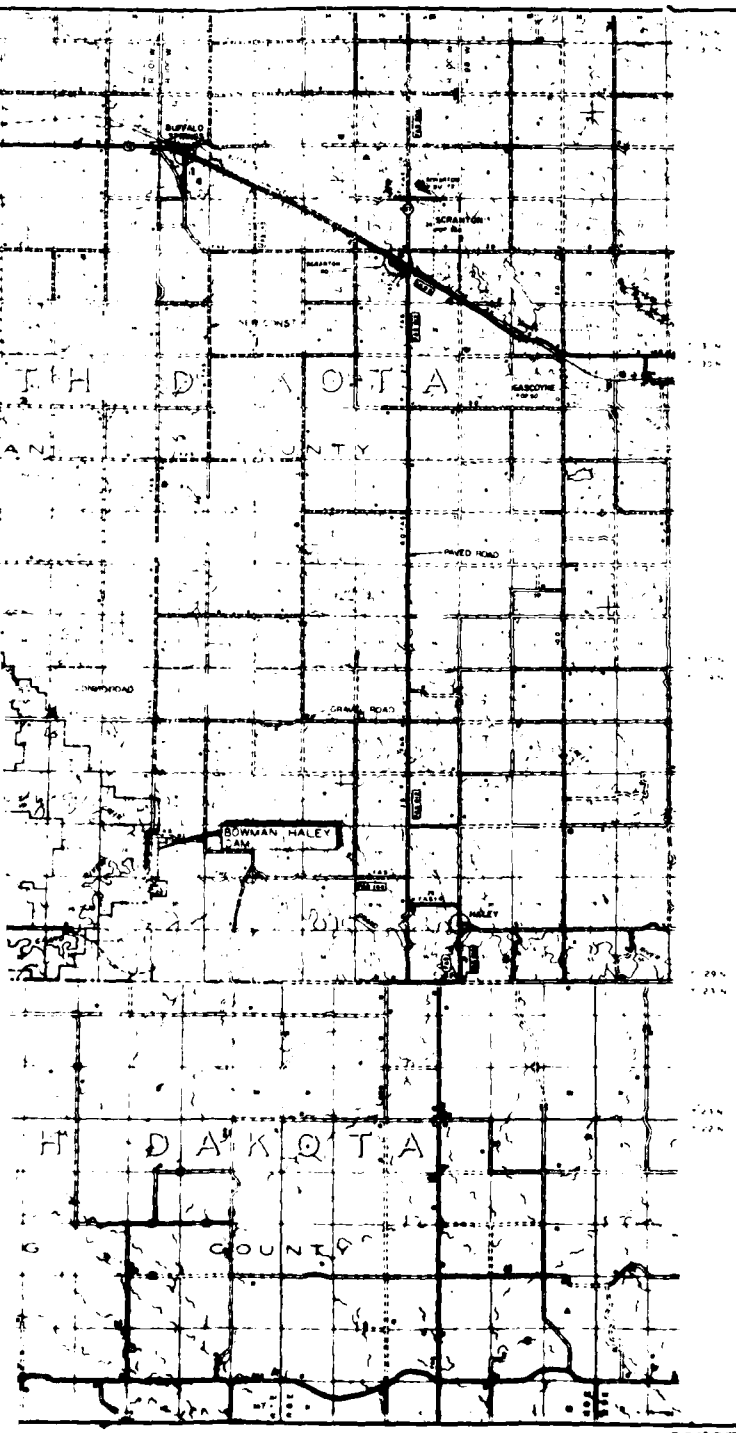
DRAWINGS

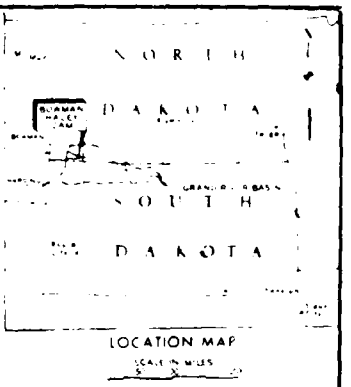
CORPS OF ENGINEERS



CONSTRUCTION

U. S. ARMY





LOCATION MAP

LEGEND

PAVED ROAD

GRAVEL SURFACED ROAD

UNSURFACED ROAD

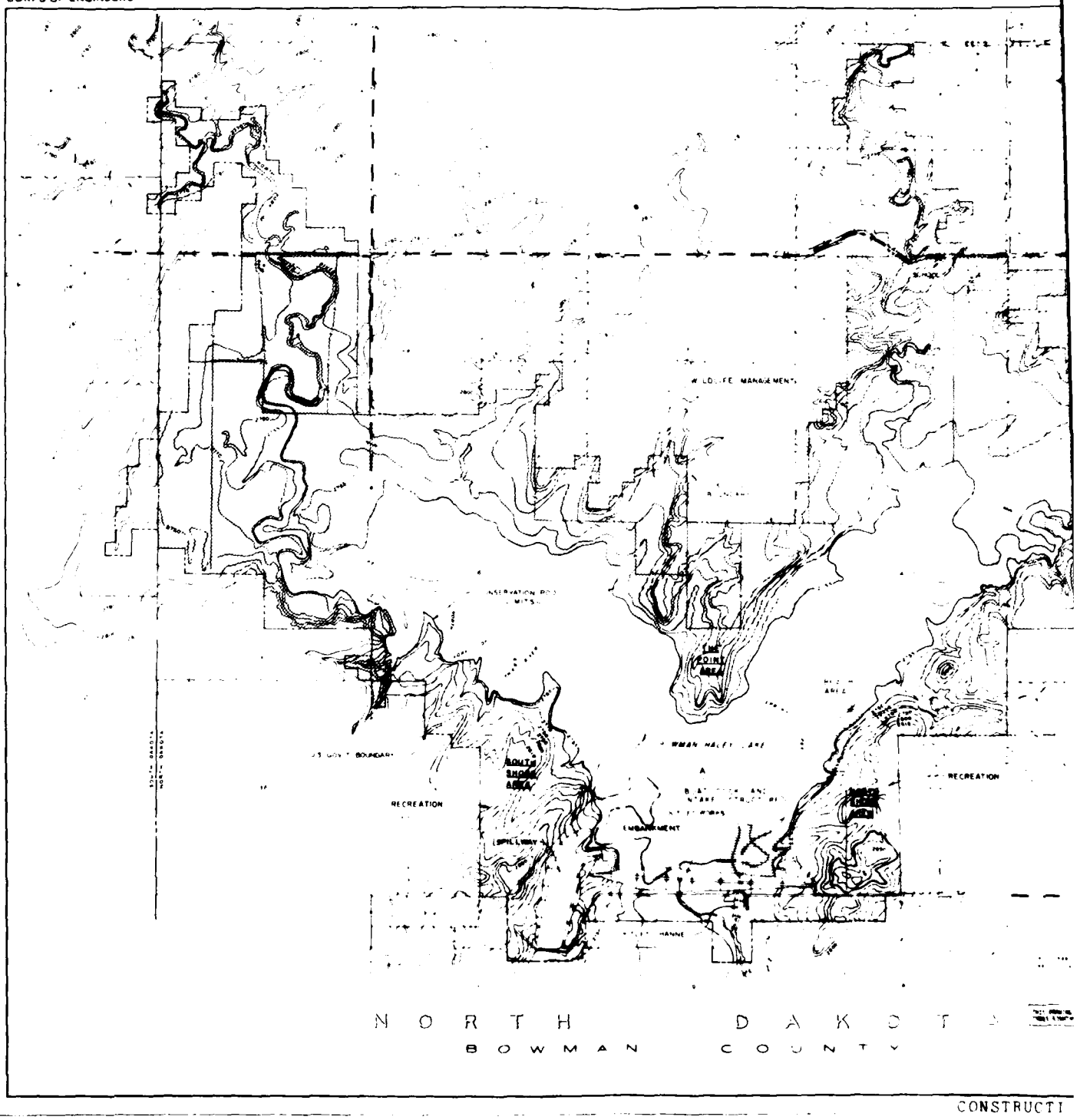
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

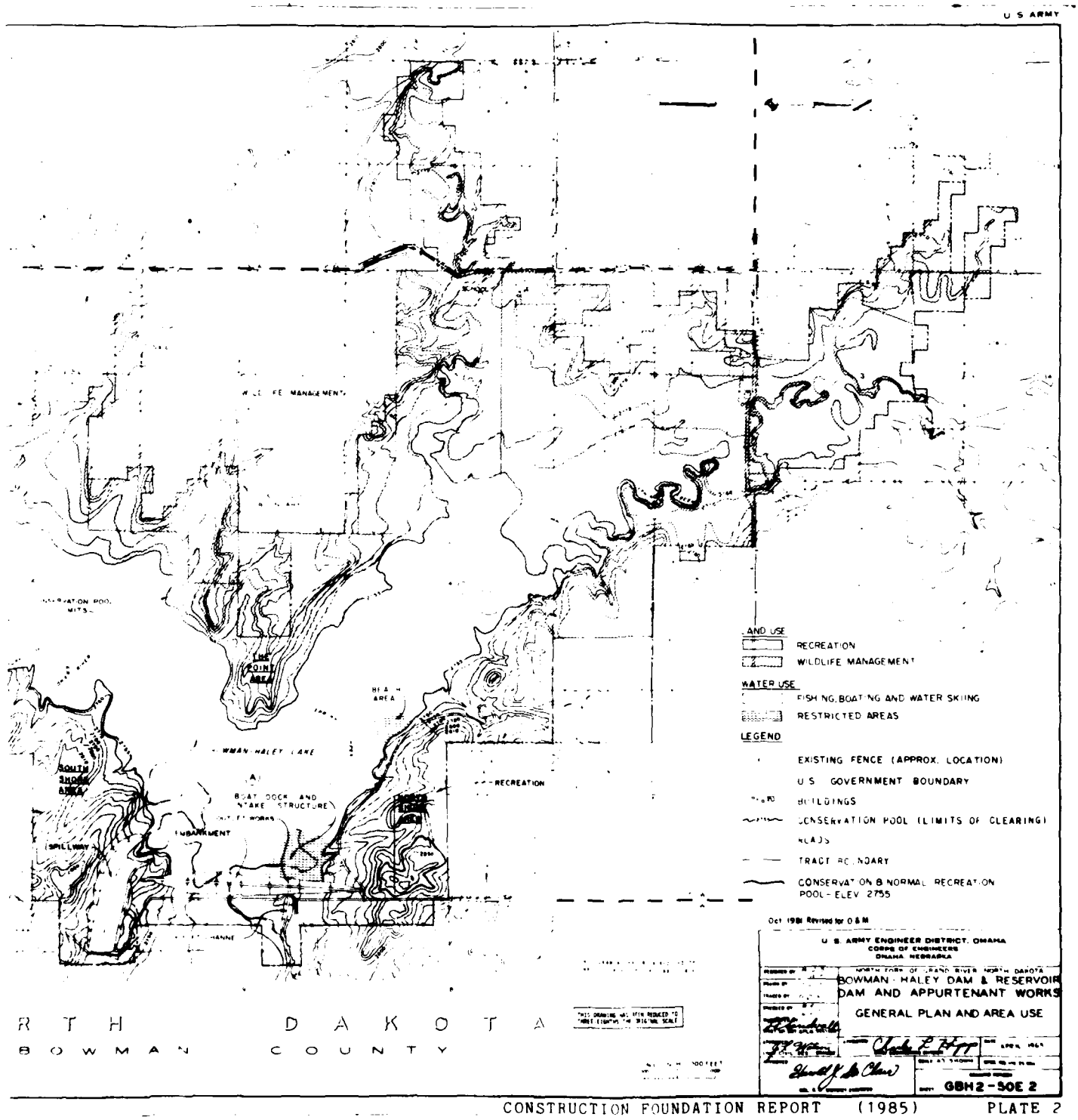
NORTH FORK OF GRAND & VER, NORTH DAKOTA
BOWMAN - HALEY DAM & RESERVOIR
OUTLET WORKS CONDUIT
PROJECT LOCATION MAP
AND INDEX

GBHI-61E1

CORPS OF ENGINEERS



CONSTRUCTI



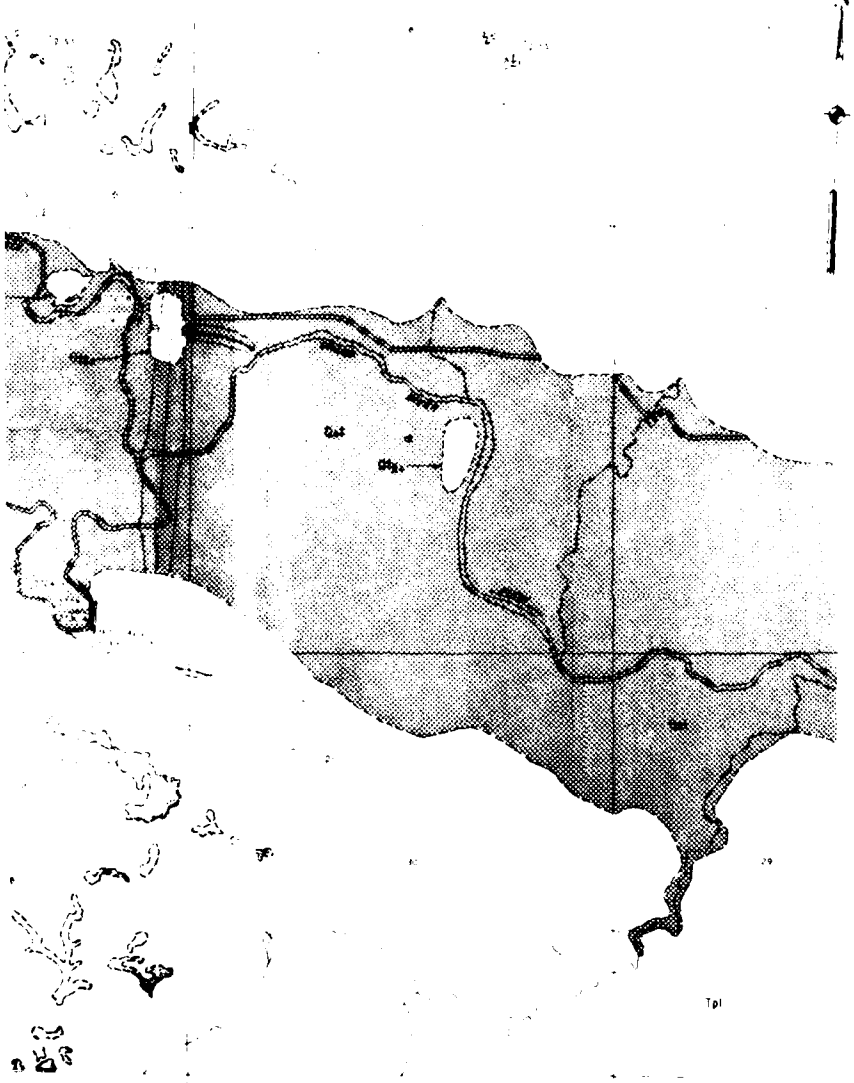
CONSTRUCTION FOUNDATION REPORT (1985) PLATE 2

CORPS OF ENGINEERS



CON.

U. S. ARMY



LEGEND

GENERAL NOTE

THIS DRAWING HAS BEEN REDUCED TO
HALF SIZE FROM THE ORIGINAL SCALE

DATE	DESCRIPTION	MADE	APPRD

REVISIONS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

BOWMAN-HALEY DAM & RESERVOIR

PRELIMINARY AREAL GEOLOGIC MAP

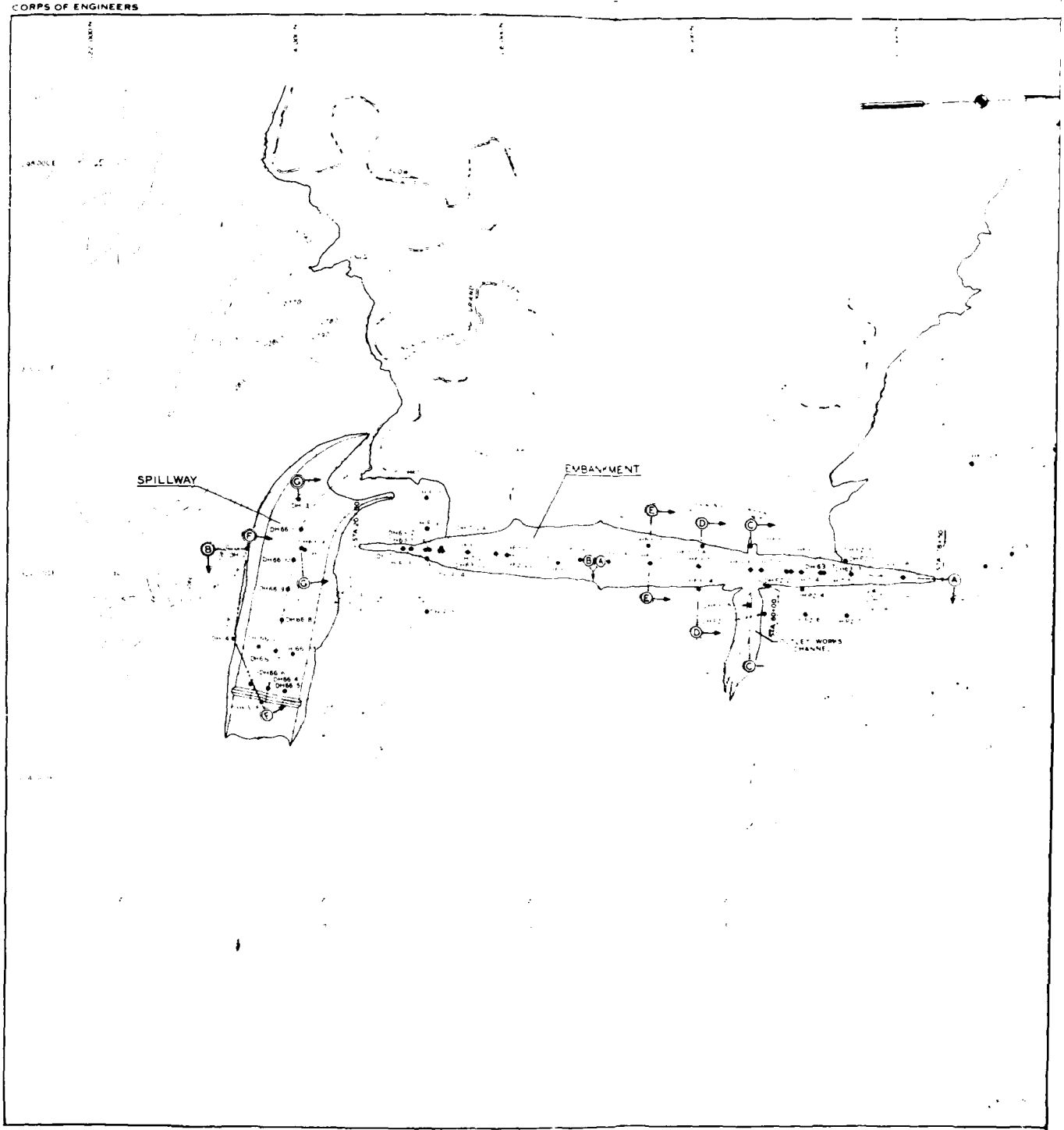
DESIGNED BY A.E.H.
DRAWN BY R.M.
TRACED BY R.M.
CHECKED BY A.E.H.
GEOLOGY
APPROVED Charles L. Hupp
CHIEF, ENGINEERING DIVISION
DATE JULY 1983
APPROVED
CHIEF, CIVIL WORKS BRANCH
SCALE AS SHOWN
DRAWING NUMBER
SHEET

SCALE 1 INCH = 660 FEET

SAFETY PAYS

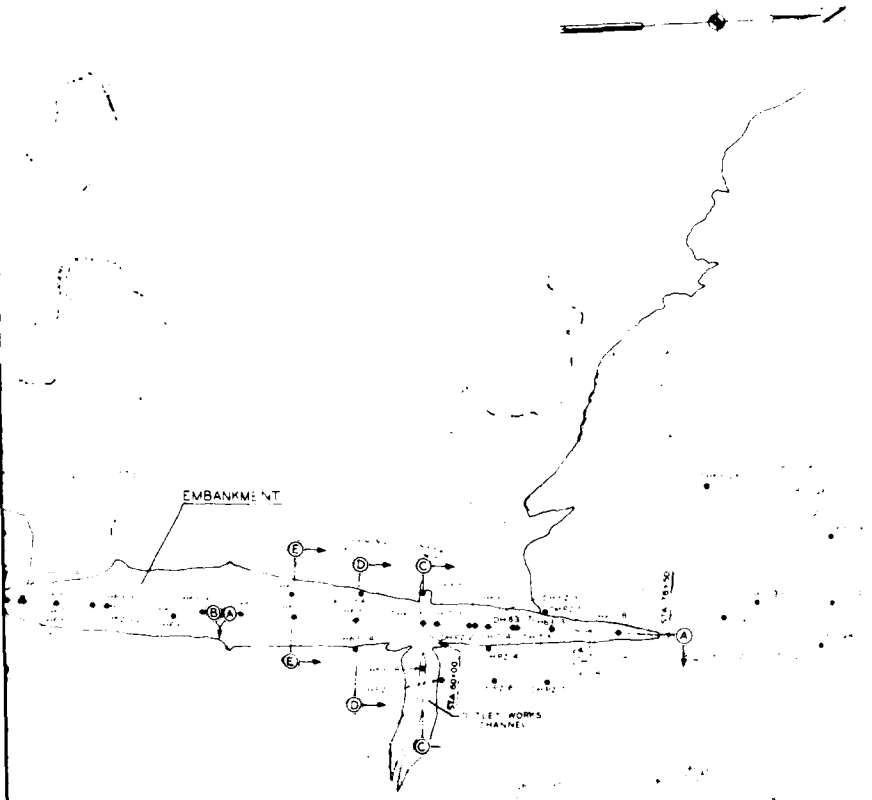
THIS PLAN ACCOMPANIES CONTRACT NO. DA-25-066-
MODIFICATION NO.

CORPS OF ENGINEERS



CONSTR

U S ARMY



LEGEND

- DH 63 — DRILL HOLE NUMBER AND LOCATION
- DH P 2 — PIEZOMETER HOLES-1963
- DH T 3 — WATER PRESSURE TEST HOLES
- DH PZ — PIEZOMETER HOLES-1969

NOTE:

Oct 1981 Revised for O & M

U S ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA NEBRASKA

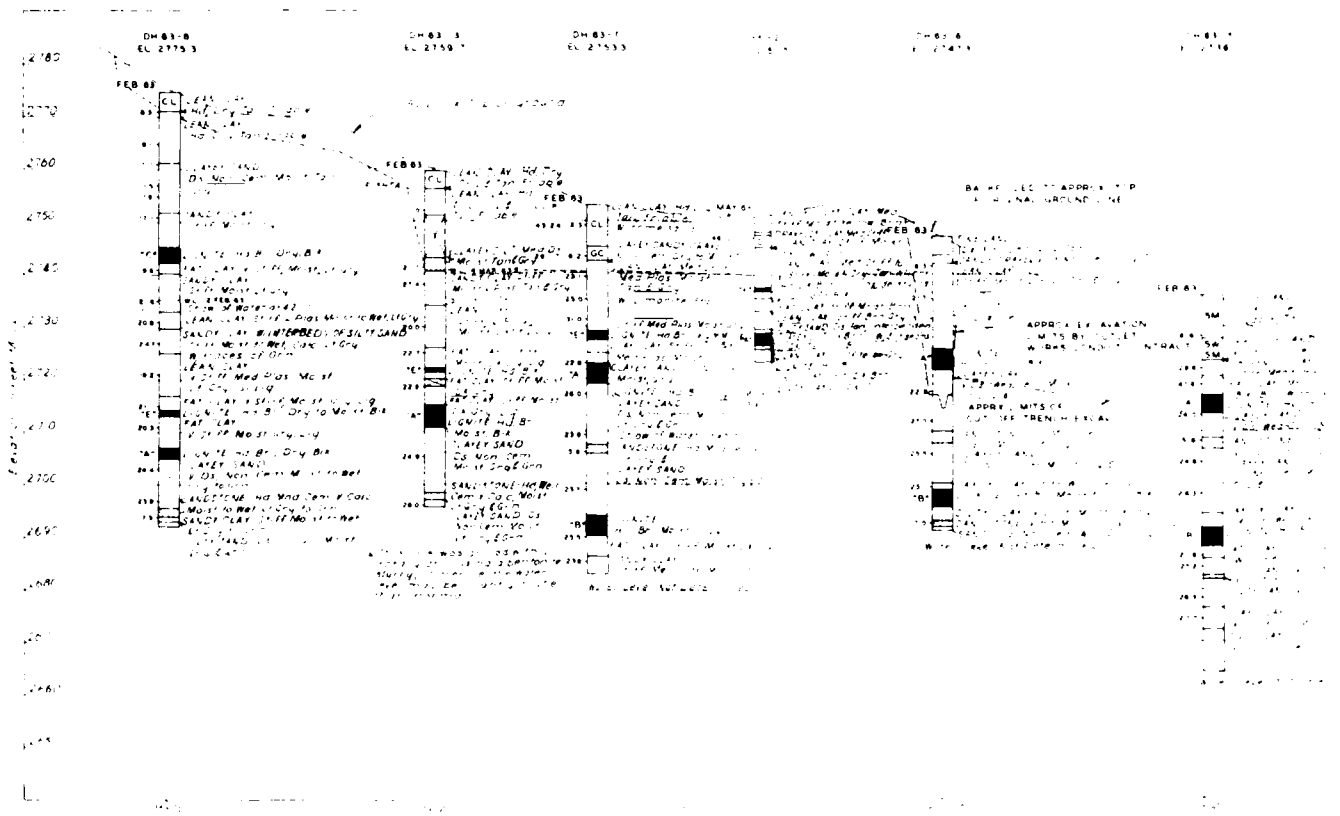
[illegible] DAM & RESERVOIR
DAM AND APPURTENANT WORKS
PLAN OF BORINGS

Clark L. Hipp

GBH 2-50E 20

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 4

CORPS OF ENGINEERS



SCALE VERT. INCH = FEET
HORIZ. INCH = FEET

LEGEND

Drill Hole Number
M.S.L. Elevation

Date of drilling

Percent of moisture at time of drilling determined by laboratory test.

(L.L.) Liquid Limit

(P.I.) Plasticity Index

Soil Classification based on laboratory tests, Atterberg limits, mechanical analysis and visual examination.

Soil Classification based on visual inspection in the field.

Water Level and date of observation. Established by measurement in open holes or piezometers.

Top of Ludlow Formation (both soil and rock terms used to describe the Ludlow Formation)

The principal lignites used for correlation are indicated by the letters "A", "B" etc.

Core Loss

Proposed excavation limits this contract.

Excavation limits by previous contract.

GENERAL NOTES:

1. The data shown graphically and by symbol for each respective boring represents the actual geologic features observed and logged at the location given on the drawings. While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of this region are anticipated and, if encountered, such variations will not be considered as differing "materially" with in the purview of Article IV of the contract.

2. The Ludlow Formation consists of soft to very stiff clays, medium dense to very dense, fine-grained sands, soft to hard, thin-bedded sandstones, soft shales and soft to hard Lignites.

3. Descriptions of material, based on visual inspection in the field, are shown to the right of the graphic log.

4. Absence of water readings in the Graphic Log of any boring is not necessarily to be construed that ground water will not be encountered in excavation at that location.

5. Information on material has been condensed in the Graphic Logs. Additional information is shown on field logs, which may be inspected at the Omaha District Office.

6. Overburden sampling was accomplished by using a percussion type drill using a 6 inch inside diameter open end drive barrel, although a rotary drill was used at some locations. The Ludlow Formation was drilled with both a percussion type drill with either a 4 or 6 inch inside diameter open end drive barrel and a rotary drill using a 5 3/8 inch diameter double-tube core barrel or Dennison barrel, using heystellite slug bits.

ABBREVIATIONS

Amount	Amt	Lig
Black	Blk	Lig
Brittle	Brit	Loe
Brown	Brn	Med
Calcareous	Calc	Mod
Carbonaceous	Carb	occ
Cemented	Cem	Pla
Concretions	Conc	Sal
Dark	Dk	Sli
Dense	Ds	ver
Gray	Gry	wea
Green	Grn	Wea
Hard	Hd	wit
High	H	

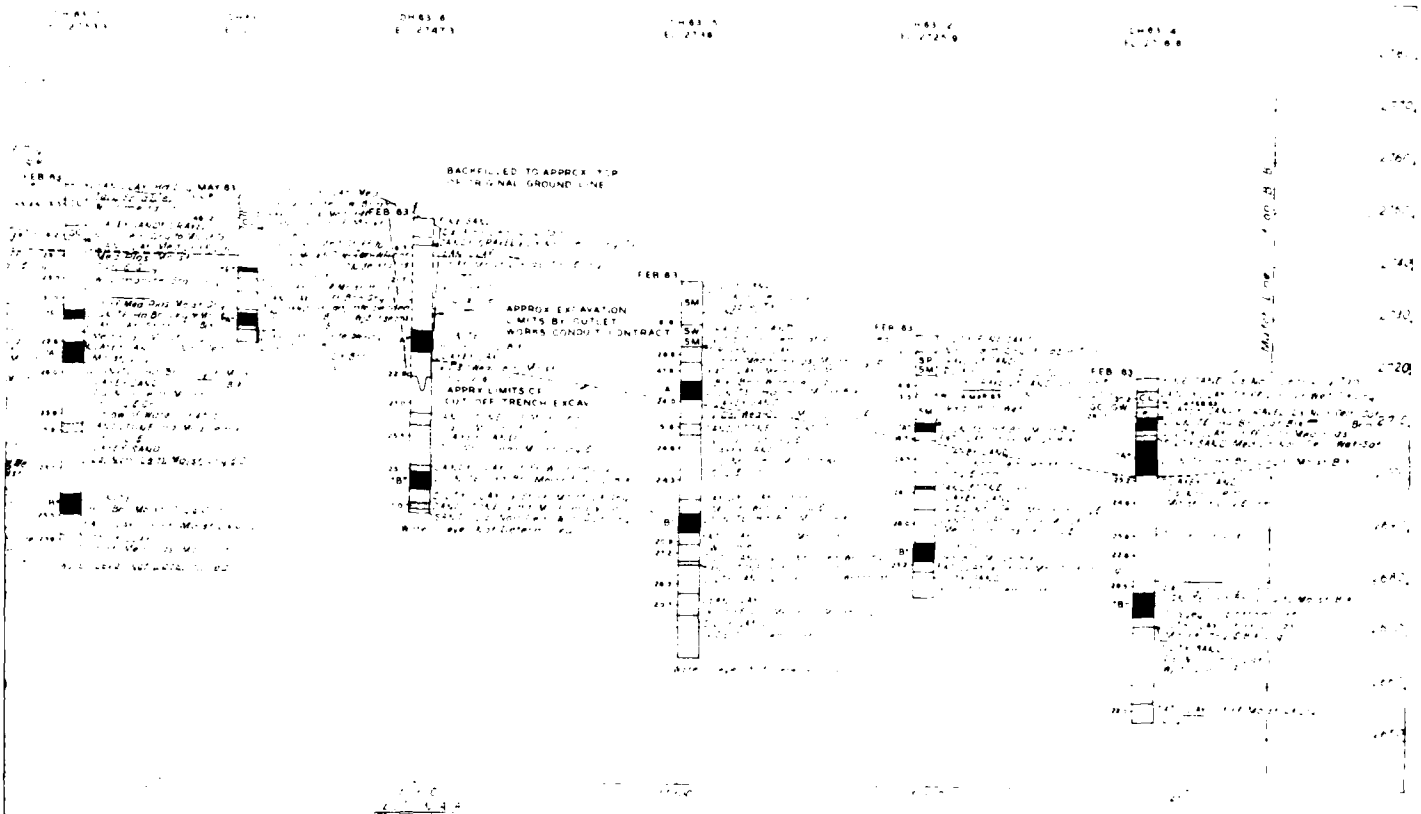
CLASSIFICATION OF SOILS:

GW	GRAVEL OR SANDY GRAVEL,
GC	CLAYEY GRAVEL OR CLAYEY
SW	SAND OR GRAVELLY SAND,
SP	SAND OR GRAVELLY SAND,
SM	SILTY SAND OR SILTY GRA
SC	CLAYEY SAND OR CLAYEY G
ML	SILTS, SANDY SILTS, GRA OR CLAYEY SILTS
CL	LEAN CLAYS, SANDY CLAYS OR GRAVELLY CLAYS
CH	FAT CLAYS

CONSTRU

A 105 Micromask Film or a Paper Reproducible Record Copy Must Be Made Before Every Amendment and/or Modification
AMENDMENT NO.
DATE
MODIFICATION NO.
DATE

U. S. ARMY



SCALE VERT 1 INCH=10 FEET
HORIZ 1 INCH=100 FEET

GENERAL NOTES:

1. The data shown graphically and by symbol for each respective boring represents the actual geologic features observed and logged at the location given on the drawings. While the borings are representative of subsurface conditions at their respective locations and for their respective vertical reaches, local variations characteristic of the subsurface materials of this region are anticipated and, if encountered, such variations will not be considered as differing "materially" within the purview of Article IV of the contract.

2. The Ludlow Formation consists of soft to very stiff clays, medium dense to very dense, fine-grained sands, soft to hard, thin-bedded sandstones, soft shales and soft to hard Lignites.

3. Descriptions of material, based on visual inspection in the field, are shown to the right of the graphic log.

4. Absence of water readings in the Graphic Log of any boring is not necessarily to be construed that ground water will not be encountered in excavation at that location.

5. Information on material has been condensed in the Graphic Logs. Additional information is shown on field logs, which may be inspected at the Omaha District Office.

6. Overburden sampling was accomplished by using a percussion type drill using a 6 inch inside diameter open end drive barrel, although a rotary drill was used at some locations. The Ludlow Formation was drilled with both a percussion type drill with either a 4 or 6 inch inside diameter open end drive barrel and a rotary drill using a 5 3/8 inch diameter double-tube core barrel or Dennison barrel, using hevetallite slug bits.

ABBREVIATIONS

Amount	Amt	Light	Lt.
Black	Blk	Lignite, Lignitic	Lig
Brittle	Brt	Low	L
Brown	Brn	Medium	Med
Calcareous	Calc	Moderately	Mod
Carbonaceous	Carb	Occasional	Occ
Cemented	Cem	Plasticity	Plas
Concretions	Conc	Saturated	Sat
Dark	Dk	Slightly	Sl
Dense	De	Very	V
Gray	Gry	Weakly	Wea
Green	Grn	Weathered	Weath
Hard	Hd	With	W
High	H		

CLASSIFICATION OF SOILS:

GW	GRAVEL OR SANDY GRAVEL, WELL GRADED
GC	CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL
SW	SAND OR GRAVELLY SAND, WELL GRADED
SP	SAND OR GRAVELLY SAND, POORLY GRADED
SM	SILTY SAND OR SILTY GRAVELLY SAND
SC	CLAYEY SAND OR CLAYEY GRAVELLY SAND
ML	SILTS, SANDY SILTS, GRAVELLY SILTS OR CLAYEY SILTS
CL	LEAN CLAYS, SANDY CLAYS, SILTY CLAYS OR GRAVELLY CLAYS
CH	FAT CLAYS

NOTES:

1. All elevations shown refer to feet above M.S.L., 1929 General Adjustment.
2. For Boring Locations, see [illegible]

THIS DRAWING WAS REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

SAFETY PAYS

Oct 1981 Revised for O & M

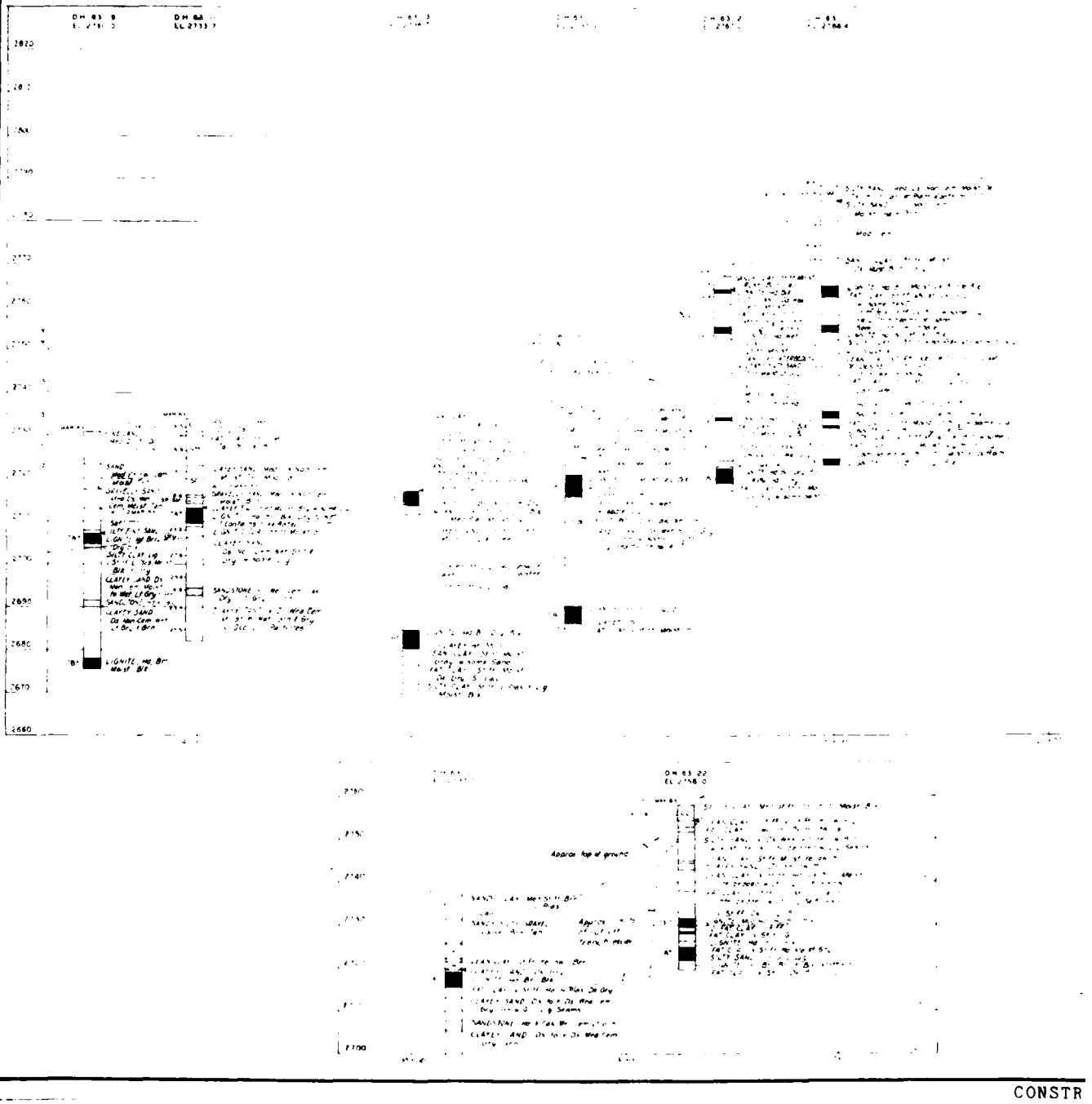
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

BOWMAN-HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
RECORD OF BORINGS
SECTION A-A AND BORING LEGEND

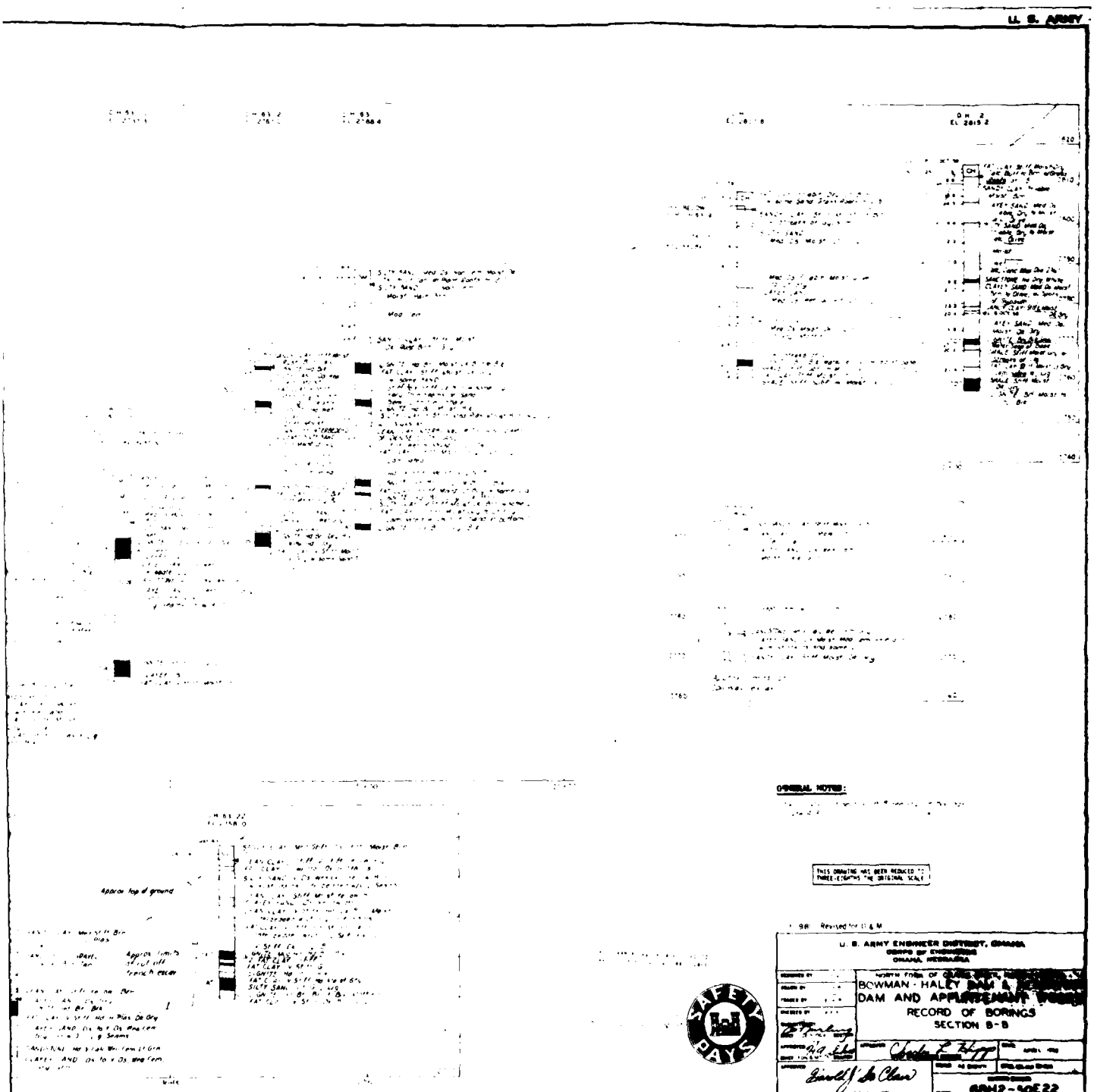
Charles E. Hopp — Apr 1985

GBH 2-50E 21

CORPS OF ENGINEERS

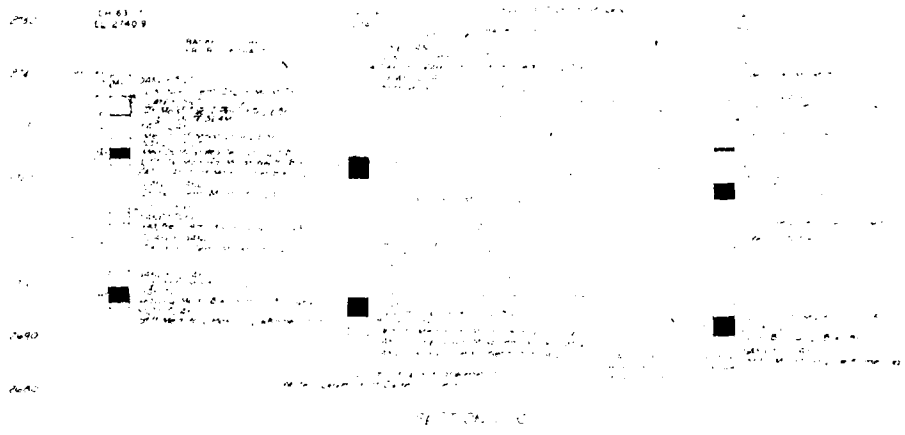


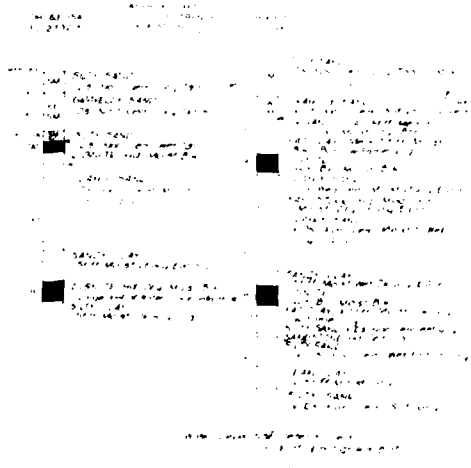
CONSTR

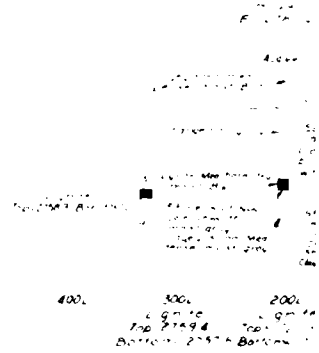


CONSTRUCTION FOUNDATION REPORT (1985) PLATE 6

CORPS OF ENGINEERS

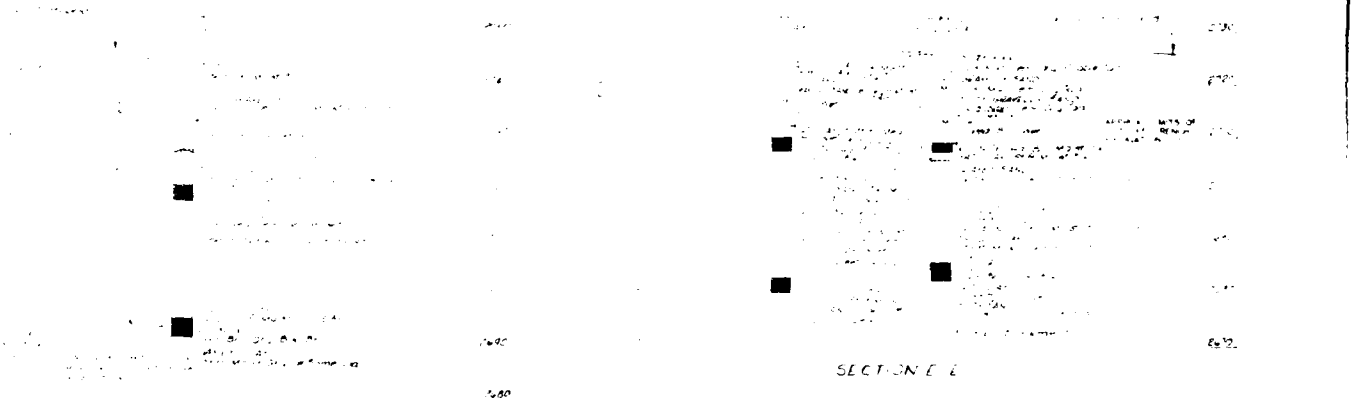


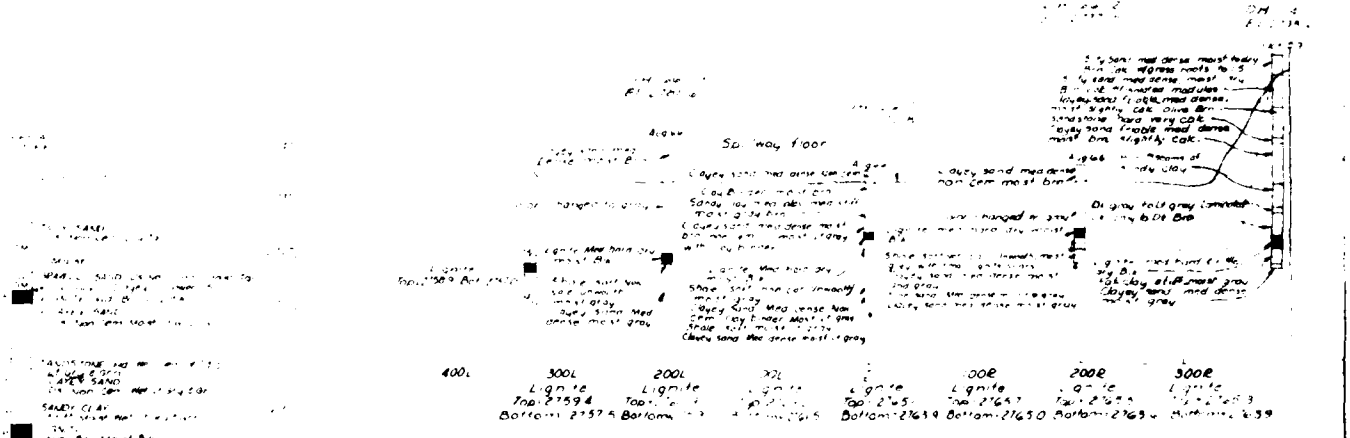




CONSTRU

U. S. ARMY





SPILLWAY SECTION AT STA 23+00

Vert 1"=10' Horiz 1"=50'

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTS THE ORIGINAL SCALE

38 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

DESIGNED BY AEE
DRAWN BY GAD
TRACED BY GAD
CHECKED BY AEE

NORTH FORK OF GRAND RIVER, GRAND RIVER BASIN

BOWMAN - HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
RECORD OF BORINGS
SECTIONS C-C, D-D AND E-E

APPROVED Charles E. Hoppe

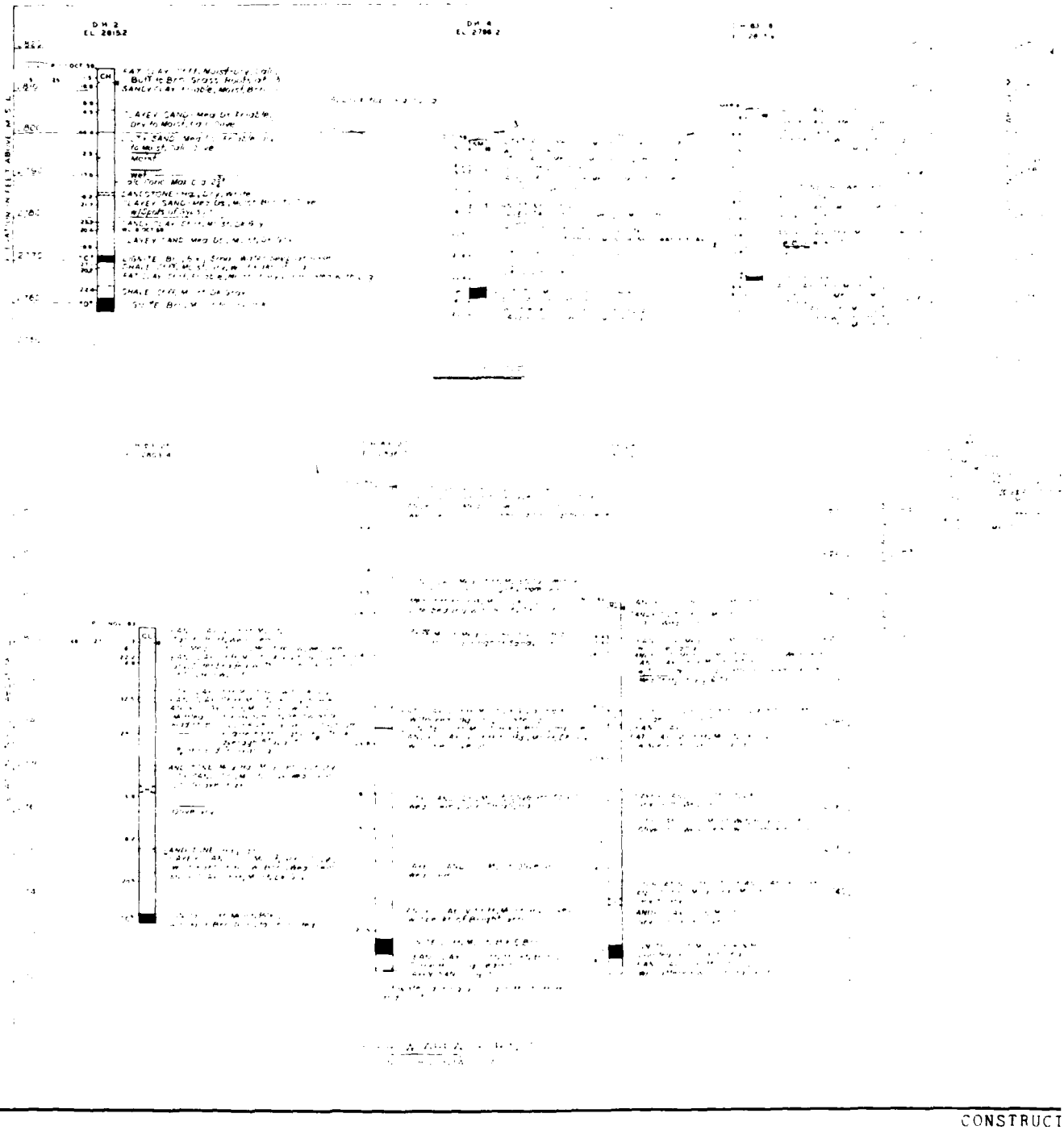
APPROVED Harold V. McClure

DATE

SHEET NO. GBH2-50E23

SAFETY DAM

CORPS OF ENGINEERS

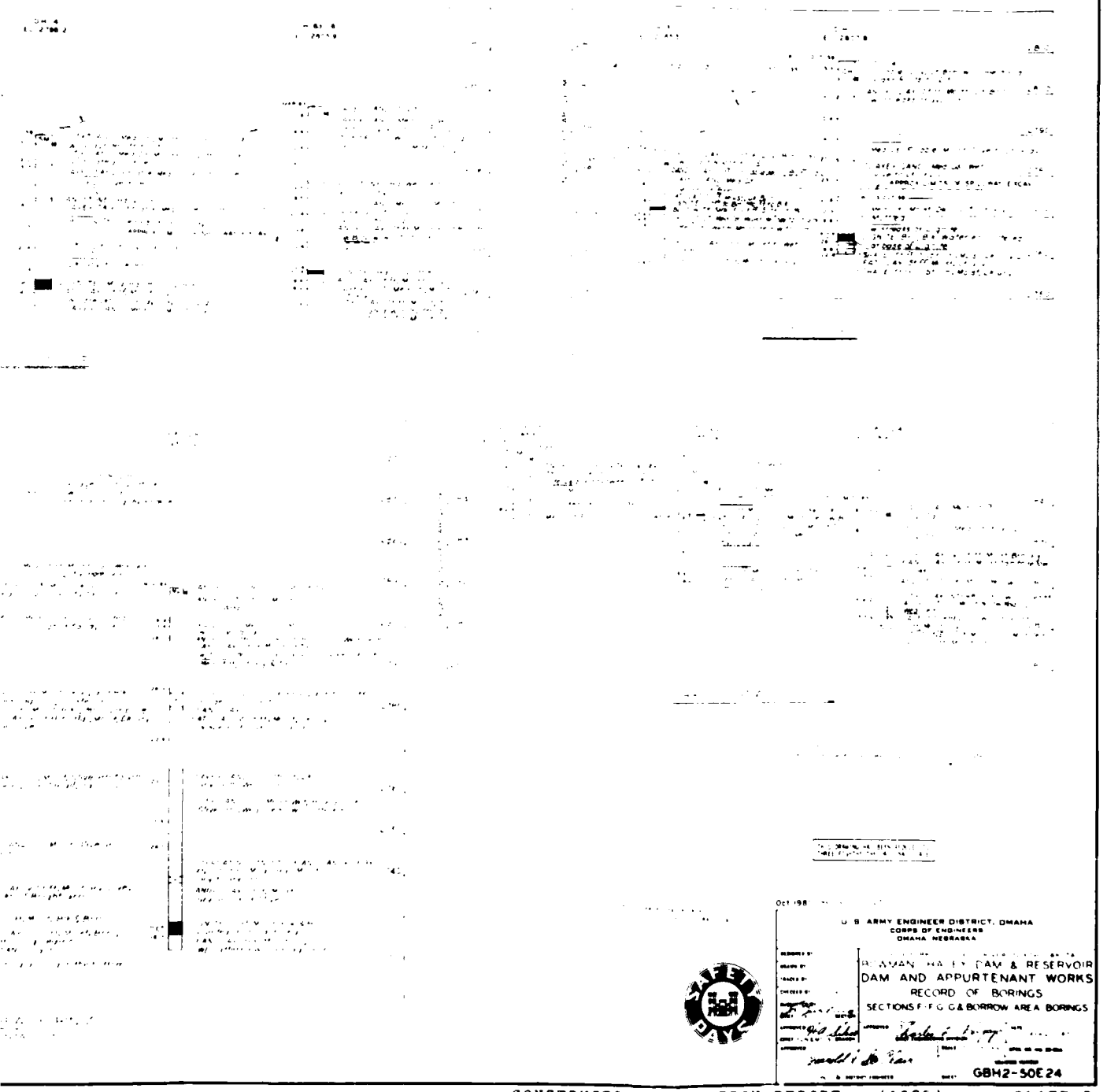


A 105 Micromaster Film or a Paper Reproducible Record
Copy Must Be Made Every Amendment and/or Modification

AMENDMENT NO.	DATE	MODIFICATION NO.	DATE

CONSTRUCT

U. S. ARMY



Oct 198

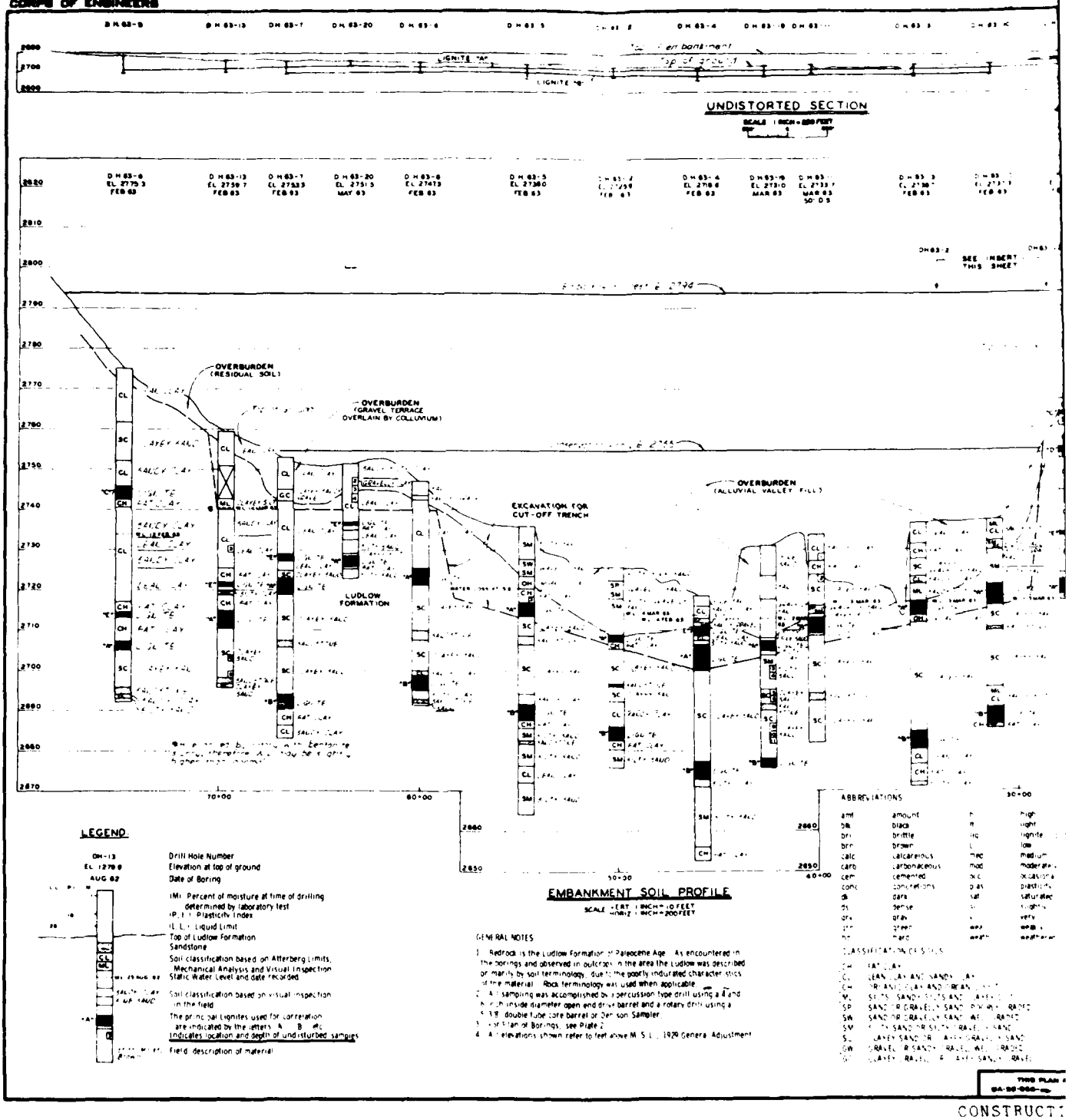
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

BOWMAN HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
RECORD OF BORINGS
SECTIONS F, F G, G & BORROW AREA BORINGS

GBH2-50E24

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 8

CORPS OF ENGINEERS



EMBANKMENT SOIL PROFILE

SCALE: HORIZ. 1 INCH = 100 FEET, VERT. 1 INCH = 10 FEET

LEGEND

- DH-13 — Drill Hole Number
- EL. 1270.8 — Elevation at top of ground
- AUG 62 — Date of Boring
- (M) — Percent of moisture at time of drilling determined by laboratory test
- P.I. — Plasticity Index
- L.L. — Liquid Limit
- Top of Ludlow Formation
- Sandstone
- Soil classification based on Atterberg Limits, Mechanical Analysis and Visual Inspection
- Static Water Level and date recorded
- Soil classification based on visual inspection in the field
- The principal lignites used for correlation are indicated by the letters A, B, etc. Indicates location and depth of undisturbed samples
- Field description of material

GENERAL NOTES

1. Bedrock is the Ludlow Formation of Paleocene Age. As encountered in the borings and observed in outcrops in the area the Ludlow was described or mainly by soil terminology, due to the poorly indurated character-stics of the material. Rock terminology was used when applicable.
2. All sampling was accomplished by a percussion type drill using a 4 and a 6 inch inside diameter open end drive barrel and a rotary drill using a 5 3/8" double tube core barrel or Denison Sampler.
3. For Plan of Borings, see Plate 2.
4. All elevations shown refer to feet above M.S.L., 1929 General Adjustment.

ABBREVIATIONS

amt	amount	h	high
blk	black	brit	brittle
brn	brown	l	low
calc	calcareous	med	medium
carb	carbonaceous	mod	moderate
cem	cemented	occ	occasional
conc	concretions	plas	plasticity
dk	dark	sat	saturated
ds	dense	sl	slightly
gry	gray	v	very
grn	green	wea	weak
hd	hard	weath	weathered

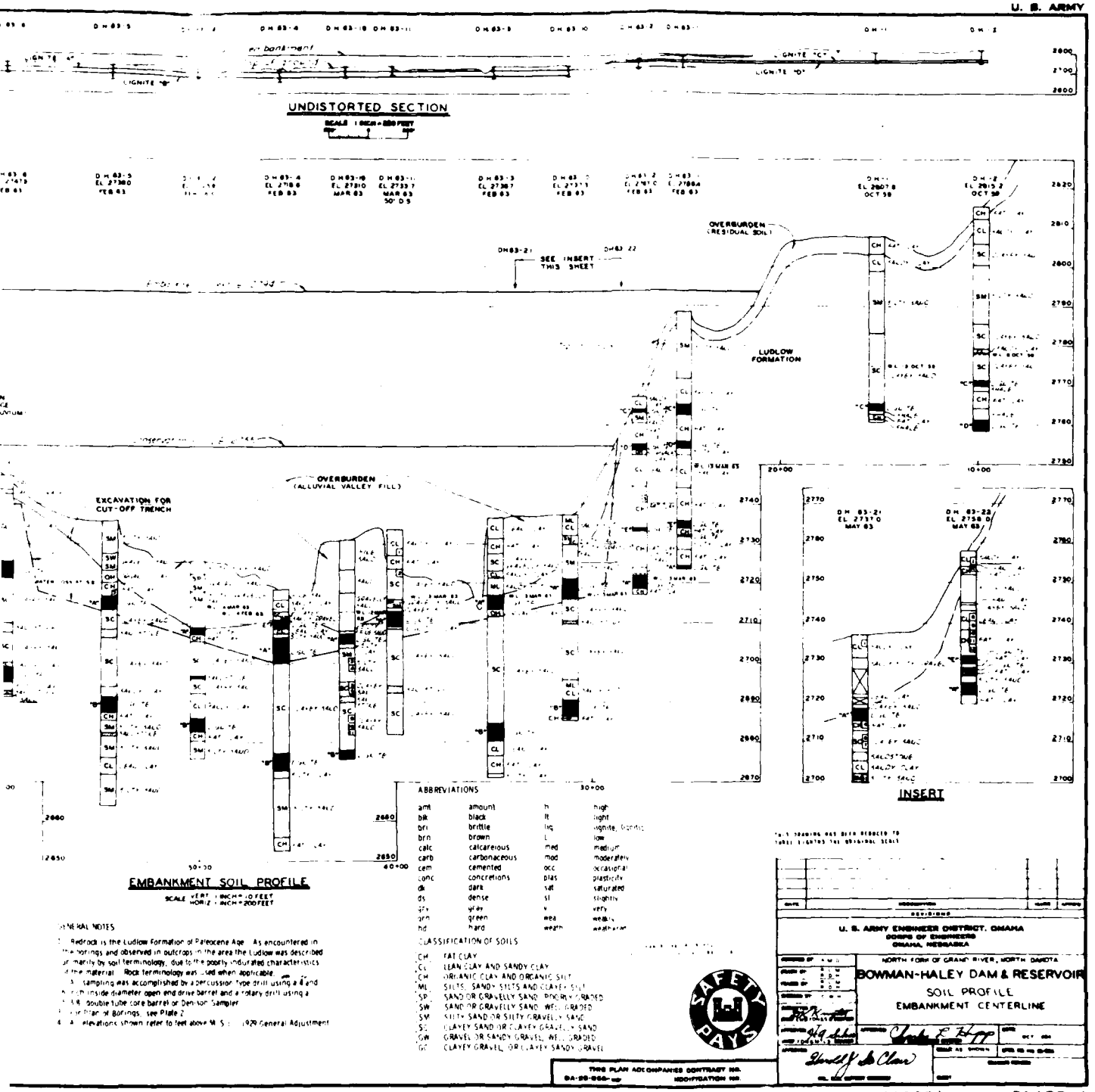
CLASSIFICATION OF SOILS

CH — FAT CLAY
CL — LEAN CLAY AND SANDY CLAY
OH — ORGANIC CLAY AND SILTY CLAY
ML — SILTS, SANDY SILTS AND CLAYEY SILTS
SP — SAND OR GRAVELLY SAND, POORLY GRADED
SW — SAND OR GRAVELLY SAND, WELL GRADED
SM — SILTY SAND OR SILTY GRAVEL AND SAND
SC — CLAYEY SAND OR CLAYEY GRAVEL AND SAND
GW — GRAVEL OR SANDY GRAVEL, WELL GRADED
GC — CLAYEY GRAVEL OR CLAYEY SAND GRAVEL

THIS PLAN

DA-20-[illegible]

CONSTRUCT



EMBANKMENT SOIL PROFILE

SCALE VERT. 1 INCH = 10 FEET
HORIZ. 1 INCH = 200 FEET

GENERAL NOTES

1. Bedrock is the Ludlow Formation of Paleocene Age. As encountered in the borings and observed in outcrops in the area the Ludlow was described primarily by soil terminology, due to the poorly indurated characteristics of the material. Rock terminology was used when applicable.
2. Sampling was accomplished by a percussion type drill using a 4 and 6 inch inside diameter open end drive barrel and a rotary drill using a N.X.W. double tube core barrel or Denison Sampler.
3. For Plan of Borings, see Plate 2.
4. All elevations shown refer to feet above M.S.L. 1929 General Adjustment.

ABBREVIATIONS

amt	amount	h	high
blk	black	lt	light
brt	brittle	lig	lignite, lignitic
brn	brown	L	low
calc	calcareous	med	medium
carb	carbonaceous	mod	moderately
cem	cemented	occ	occasional
conc	concretions	plas	plasticity
dk	dark	sat	saturated
ds	dense	sl	slightly
gry	gray	v	very
grn	green	wea	weakly
hd	hard	weath	weathered

CLASSIFICATION OF SOILS

CH	FAT CLAY
CL	LEAN CLAY AND SANDY CLAY
OH	ORGANIC CLAY AND ORGANIC SILT
ML	SILTS, SANDY SILTS AND CLAYEY SILT
SP	SAND OR GRAVELLY SAND, POORLY GRADED
SW	SAND OR GRAVELLY SAND, WELL GRADED
SM	SILTY SAND OR SILTY GRAVELLY SAND
SC	CLAYEY SAND OR CLAYEY GRAVELLY SAND
GW	GRAVEL OR SANDY GRAVEL, WELL GRADED
GC	CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO. DA-25-066-

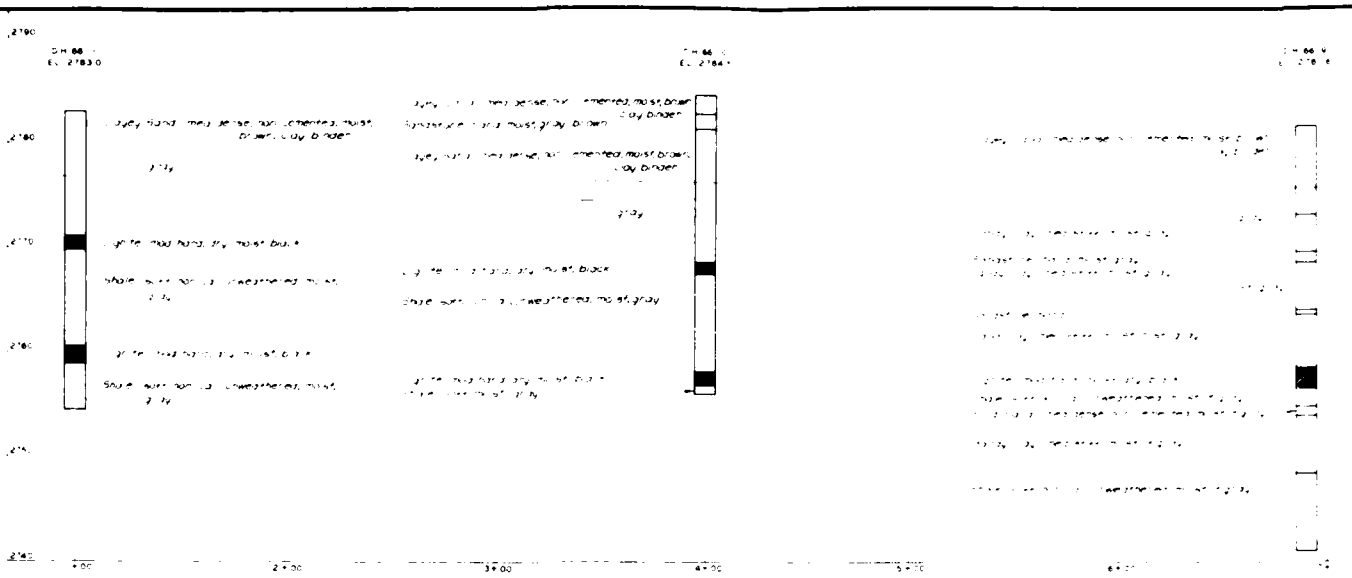
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

BOWMAN-HALEY DAM & RESERVOIR

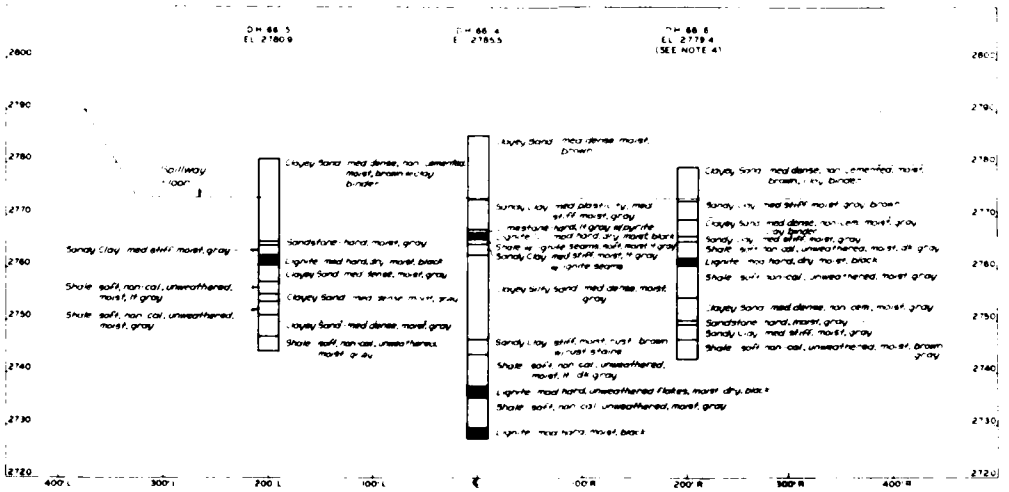
SOIL PROFILE
EMBANKMENT CENTERLINE

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 9



PROFILE ALONG SPILLWAY CENTERLINE

SCALE

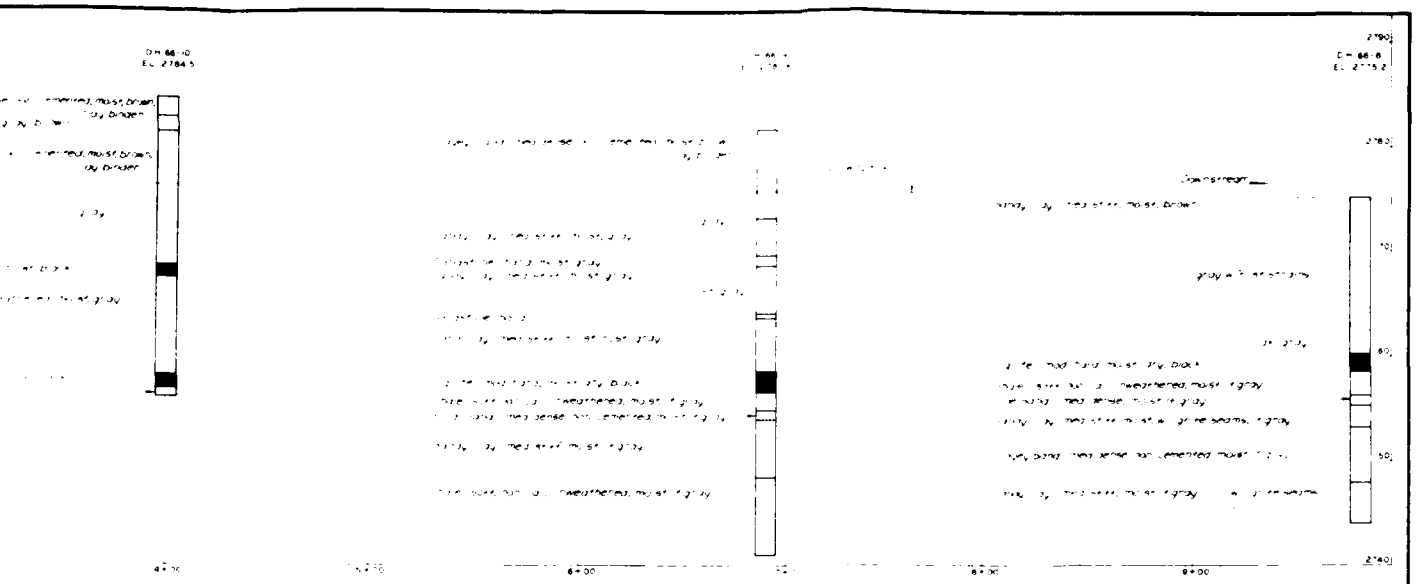


SPILLWAY SECTION AT STA. 26+50

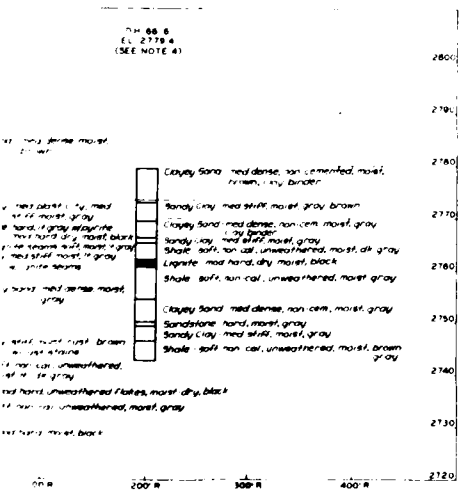
SCALE VERT. 1 INCH = 10 FEET
HORIZ. 1 INCH = 50 FEET

$$ – THINK VALUE ENGINEERING – $$

CONSTRUCTION



PROFILE ALONG SPILLWAY CENTERLINE



A. 26+50

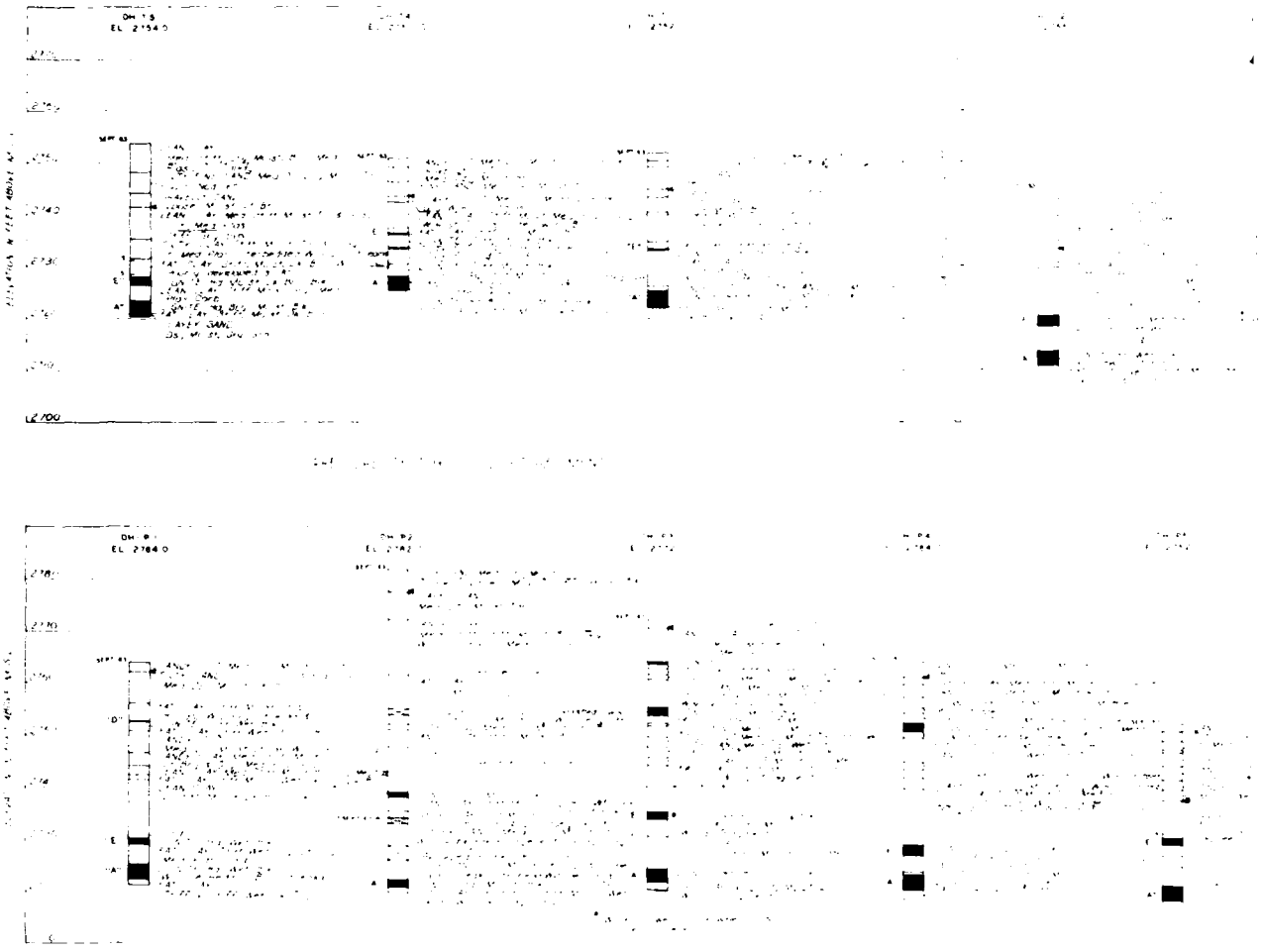
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM AND RESERVOIR
DAM AND APPURTENANT WORKS
RECORD OF BORINGS
SPILLWAY SECTION AND PROFILE

THIS PLAN ACCOMPANIES CONTRACT NO. DACA45 MODIFICATION NO.

SAFETY PAYS

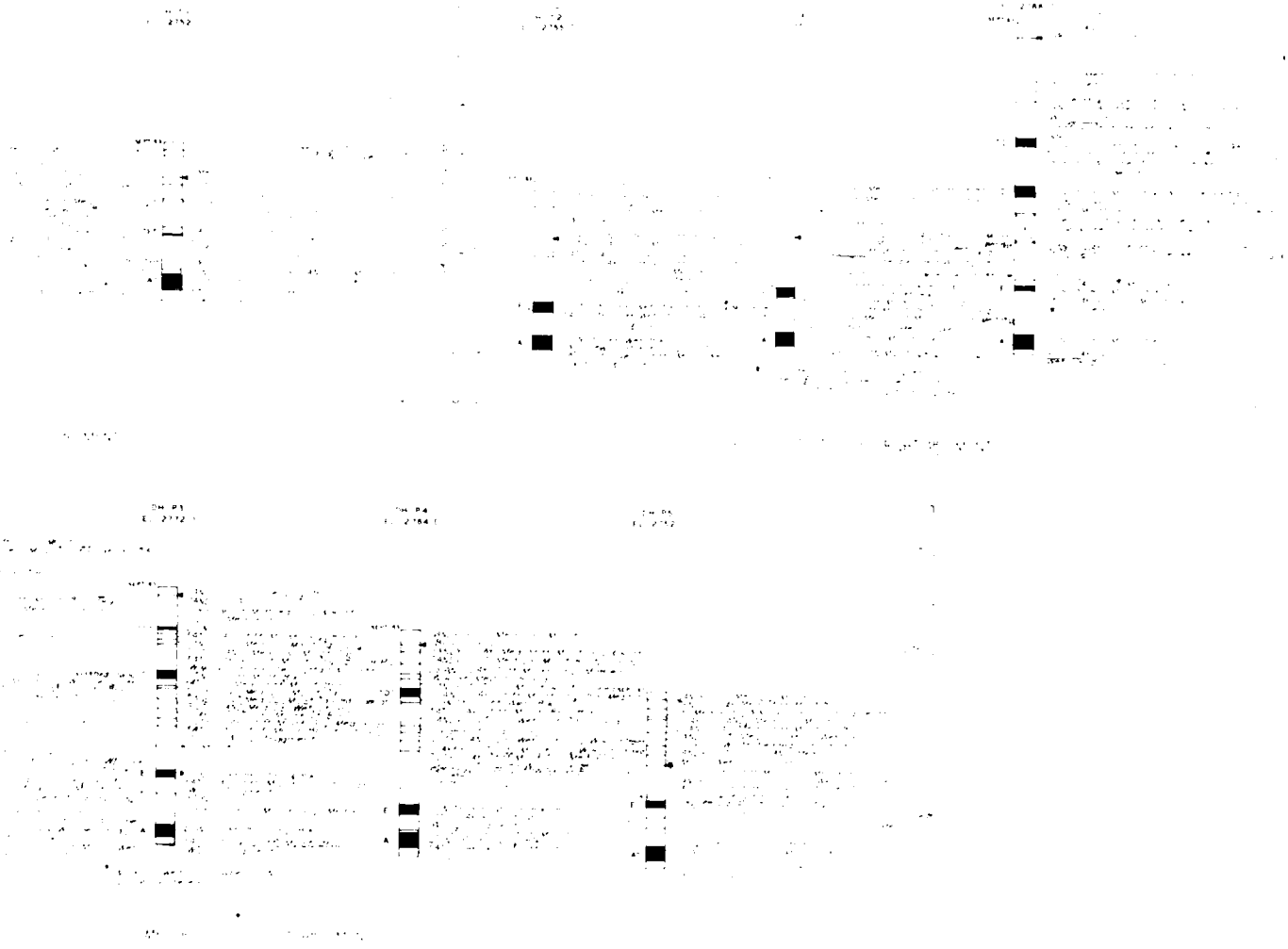
CORPS OF ENGINEERS



A 105 Micrometer Film or a Paper Reproducible Record Copy Must Be Made Before Every Amendment and/or Modification

AUTHORITY	DATE	MODIFICATION	DATE

CONSTRUCT



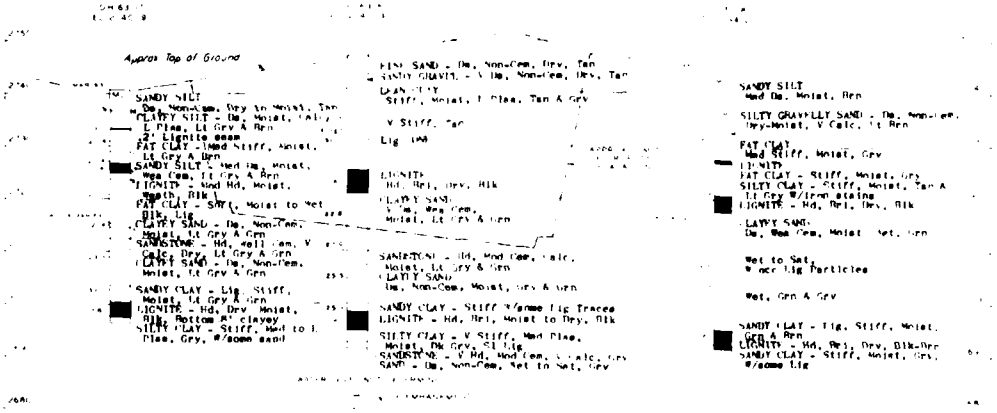
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

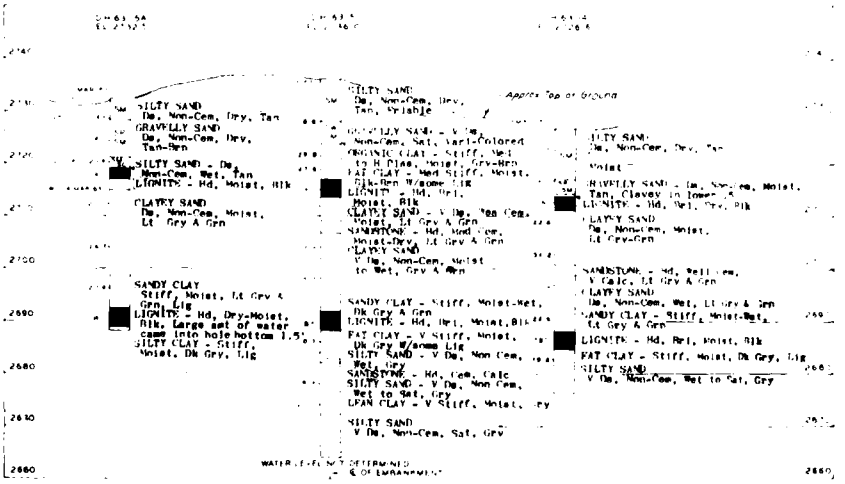
DAM AND APPURTENANT WORKS

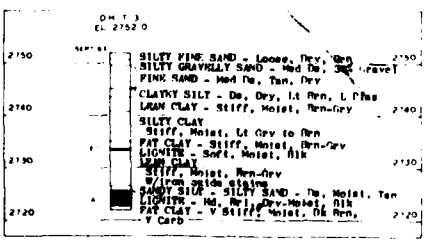
PIEZOMETER AND PRESSURE TEST HOLES

GBH2-50E25

CORPS OF ENGINEERS







CLASSIFICATION OF SOILS

SW SAND OR GRAVELLY SAND, WELL GRADED
SP SAND OR GRAVELLY SAND, POORLY GRADED
SM SILTY SAND OR SILTY GRAVELLY SAND
SC CLAYEY SAND OR CLAYEY GRAVELLY SAND
ML SILTS, SANDY SILTS, GRAVELLY SILTS
CL LEAN CLAYS, SANDY CLAYS, SILTY CLAYS

ABBREVIATIONS

Amount	Lt	Light	
Black	Lig	Lignite, L	
Brittle	Mst	Moist	
Brown	Mod	Medium	
Calcareous	Calc	Moderately	
Carbonaceous	Carb	Occasional	
Cemented	Cem	Plasticity	
Dark	Sat	Saturated	
Dense	Sl	Slightly	
Gray	Gry	Very	
Green	Grn	Weakly	
Hard	Wd	Weathered	
High			

A 105 Micrographic Film or a Paper Reproducible Record Copy Must Be Made Before Every Amendment and/or Modification

AMENDMENT	DATE	MODIFICATION	DATE

CONSTRUC

U. S. ARMY

LEGEND

DRILL HOLE NUMBER
M.S.L. ELEVATION

DATE OF DRILLING
PER CENT OF MOISTURE AT TIME OF DRILLING
DETERMINED BY LABORATORY TEST
(L.L.) LIQUID LIMIT
(P.I.) PLASTICITY INDEX

LEAN CLAY
SILTY SAND — SOIL CLASSIFICATION BASED ON LABORATORY TESTS, ATTERBURG LIMITS, MECHANICAL ANALYSIS AND VISUAL EXAMINATION

FAT CLAY
SANDY CLAY — SOIL CLASSIFICATION BASED ON VISUAL INSPECTION IN THE FIELD

WATER LEVEL AND DATE OF OBSERVATION ESTABLISHED BY MEASUREMENT IN OPEN HOLE

TOP OF THE LUDLOW FORMATION (BOTH SOIL AND ROCK TYPES) USED TO DESCRIBE THE LUDLOW FORMATION)

THE PRINCIPAL LIGNITES USED FOR CORRELATION ARE INDICATED BY THE LETTERS "A", "B", ETC.

PROPOSED EXCAVATION LIMITS

SANDY SILT
Med Dk, Moist, Brn

CLAYEY GRAVELLY SAND - Dk, Non-Coh, Dry-Moist, V Calc, Lt Brn

FAT CLAY
Med Stiff, Moist, Gry

LIGNITE
FAT CLAY - Stiff, Moist, Gry
SILTY CLAY - Stiff, Moist, Tan & Lt Gry W/iron staing
LIGNITE - Md, Brt, Dry, Blk

LAYEY SAND
Dk, Non-Coh, Moist, Wet, Brn

Wet to Sat
Micaceous Particles

Wet, Brn & Gry

SANDY CLAY - Lig, Stiff, Moist, Brn & Gry
LIGNITE - Md, Brt, Dry, Blk-Brn
SANDY CLAY - Stiff, Moist, Gry, W/some Lig

CLAYEY SAND
Dk, Non-Coh, Dry, Tan

Moist

GRAVELLY SAND - Dk, Non-Coh, Moist, Tan, Clayey in Lower .5'
LIGNITE - Md, Brt, Dry, Blk

LAYEY SAND
Dk, Non-Coh, Moist, Lt Grn-Gry

SANDSTONE - Md, Well Com, V Calc, Lt Gry & Grn
LAYEY SAND
Dk, Non-Coh, Wet, Lt Gry & Grn
SANDY CLAY - Stiff, Moist-Wet, Lt Gry & Grn
LIGNITE - Md, Brt, Moist, Blk
FAT CLAY - Stiff, Moist, Dk Gry, Lig
SILTY SAND
V Dk, Non-Coh, Wet to Sat, Gry

CLASSIFICATION OF SOILS

GW	SAND OR GRAVELLY SAND, WELL GRADED
SP	SAND OR GRAVELLY SAND, POORLY GRADED
SM	SILTY SAND OR SILTY GRAVELLY SAND
SC	CLAYEY SAND OR CLAYEY GRAVELLY SAND
ML	SILTS, SANDY SILTS, GRAVELLY SILTS OR CLAYEY SILTS
CL	LEAN CLAYS, SANDY CLAYS, SILTY CLAYS OR GRAVELLY CLAYS

ABBREVIATIONS

Amount	Amt	Light	Lt
Black	Blk	Lignite, Lignitic	Lig
Brittle	Brt	Low	L
Brown	Brn	Medium	Med
Calcareous	Calc	Moderately	Mod
Carbonaceous	Carb	Occasional	Occ
Cemented	Cem	Plasticity	Plas
Dark	Dk	Saturated	Sat
Dense	De	Slightly	Sl
Gray	Gry	Very	V
Green	Grn	Weakly	Wea
Hard	Hd	Weathered	Weath
High	H		

GENERAL NOTES:

1. THE DATA SHOWN GRAPHICALLY AND BY SYMBOL FOR EACH RESPECTIVE BORING REPRESENTS THE ACTUAL GEOLOGIC FEATURES OBSERVED AND LOGGED AT THE LOCATION GIVEN ON THIS DRAWINGS. WHILE THE BORINGS ARE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THEIR RESPECTIVE LOCATIONS AND FOR THEIR RESPECTIVE VERTICAL REACHES, LOCAL VARIATIONS CHARACTERISTIC OF THE SUBSURFACE MATERIALS OF THIS REGION ARE ANTICIPATED, AND, IF ENCOUNTERED, SUCH VARIATIONS WILL NOT BE CONSIDERED AS DIFFERING "MATERIALLY" WITHIN THE PURVIEW OF ARTICLE IV OF THE CONTRACT.
2. THE LUDLOW FORMATION CONSISTS OF SOFT TO VERY STIFF CLAYS, MEDIUM DENSE TO VERY DENSE, FINE-GRAINED SANDS, SOFT TO HARD, THIN-BEDDED SANDSTONES, SOFT SHALES AND SOFT TO HARD LIGNITES.
3. DESCRIPTIONS OF MATERIAL BASED ON VISUAL INSPECTION IN THE FIELD ARE SHOWN TO THE RIGHT OF THE GRAPHIC LOG.
4. ABSENCE OF WATER READINGS IN THE GRAPHIC LOG OF BORING IS NOT NECESSARILY TO BE CONSTRUED THAT GROUND WATER WILL NOT BE ENCOUNTERED IN EXCAVATION AT THAT LOCATION.
5. INFORMATION ON MATERIAL HAS BEEN CONDENSED IN THE GRAPHIC LOGS. ADDITIONAL INFORMATION IS SHOWN ON THE FIELD LOGS, WHICH MAY BE INSPECTED AT THE OMAHA DISTRICT OFFICE.
6. OVERBURDEN SAMPLING WAS ACCOMPLISHED BY USING A PERCUSSION TYPE DRILL USING A 5 INCH DIAMETER BALANCED OPEN END DRIVE BARREL. THE LUDLOW FORMATION WAS DRILLED WITH BOTH A PERCUSSION TYPE DRILL WITH EITHER A 4 OR 5 INCH INSIDE DIAMETER OPEN END DRIVE BARREL AND A ROTARY DRILL USING A 5 7/8 INCH DIAMETER DOUBLE-TUBE CORE BARREL OR DENISON BARREL, USING WATER/BENTONITE MUD MIX.

NOTES:

1. ALL ELEVATIONS SHOWN REFER TO FEET ABOVE M.S.L., 1929 GENERAL ADJUSTMENT.

THIS DRAWING WAS REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

U. S. GOVERNMENT HAS RIGHT TO REPRODUCE THIS DRAWING FOR GOVERNMENTAL PURPOSES

SCALE: VERT. INCH = FEET
HORIZ. INCH = FEET

SAFETY PAYS

Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

BOWMAN - HALEY DAM & RESERVOIR
OUTLET WORKS CONDUIT
RECORD OF BORINGS

DESIGNED BY: A. E. H.
DRAWN BY: C. M. B.
TRACED BY: C. M. B.
CHECKED BY: A. E. H.
GEOLOGY BRANCH
ENGINEERING DIVISION
CHIEF, ENGINEERING DIVISION: Charles E. Hoff
CHIEF, CONSTRUCTION DIVISION: Harold J. St. Clair

68HI-61E4

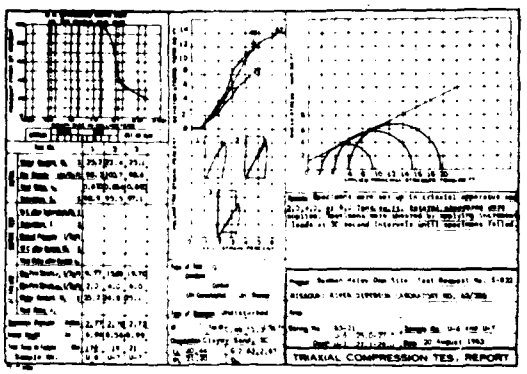


FIGURE 1

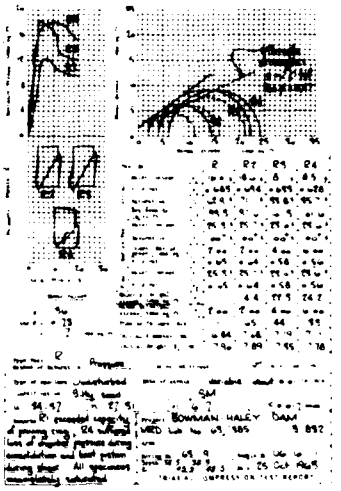


FIGURE 2

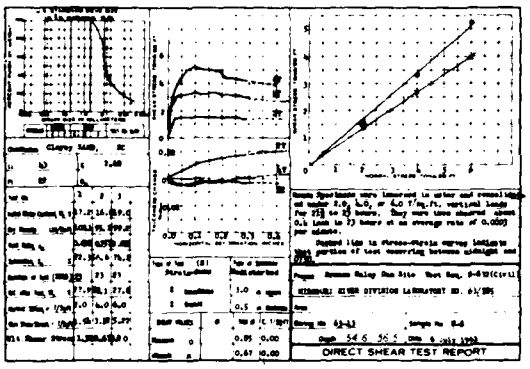


FIGURE 4

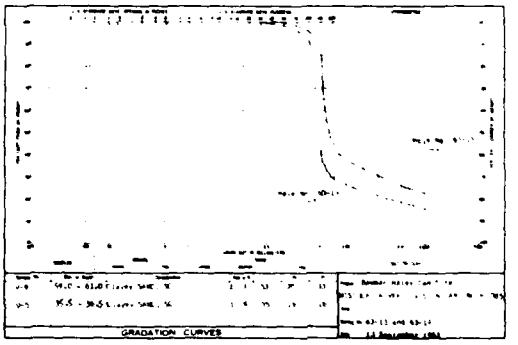


FIGURE 5

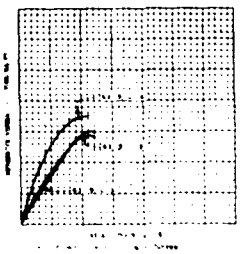
U. S. ARMY ENGINEER DIVISION, MISSOURI RIVER
CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA

TABLE 2. - UNCONFINED COMPRESSION AND CLASSIFICATION TEST DATA

TEST REQUEST NO. D-832 — MISSOURI RIVER DIVISION LABORATORY NO. 63/385

Hole No.	Sample No.	Depth (feet)	Dry Density (lbs/cu.ft.)	Moisture (percent)	ϵ_f (%)	Compressive Strength (lbs/sq.in.)	(Tons/sq.ft.)	Failure diagram	Atterberg Limits Liquid limit	Plastic limit	Classification	Remarks
63-10	UD-5	29.1-31.5	88.2	25.1	3.00	22.00	1.51		35	26	Silty SAND,	Columnar failure. Gray silty sand, Specimen contained small horizontal streaks of dark gray lignite throughout. Void ratio = 0.692.
63-10	UD-6	31.5-33.6	88.0	24.6	3.00	24.26	1.70		38	28	Silty SAND,	Columnar failure. Gray silty sand. Specimen contained small spots of dark brown lignite throughout. Void ratio = 0.695.
63-10	UD-7	46.4-48.0	99.1	20.2	3.07	19.00	1.48		41	32	Clayey SAND,	Columnar failure. Gray, clayey sand. Specimen contained streaks of light gray sand throughout and streaks of dark brown lignite to lesser extention. Void ratio = 0.672.

NOTE: ϵ_f = Axial strain (change in diameter ratio of test specimen)



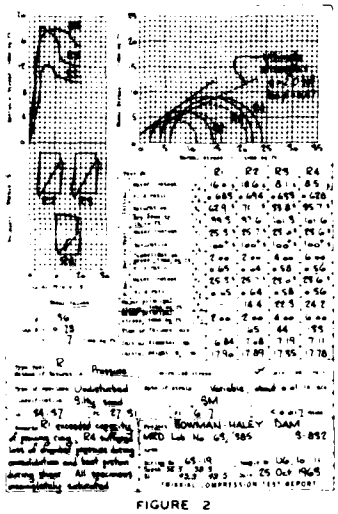


FIGURE 2

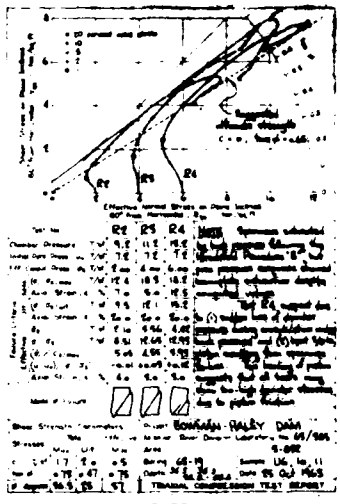


FIGURE 3

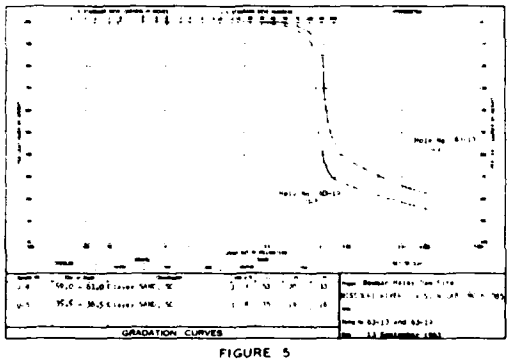
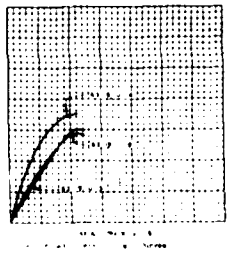


FIGURE 5

PERMEABILITY TEST
TABLE I



U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER NORTH DAKOTA

BOWMAN-HALEY DAM & RESERVOIR

FOUNDATION SOIL TEST DATA
CLAYEY SAND (LUDLOW)

THIS PLAN ACCOMPANIES CONTRACT NO.
DA-__-___-eng-___ MODIFICATION NO.

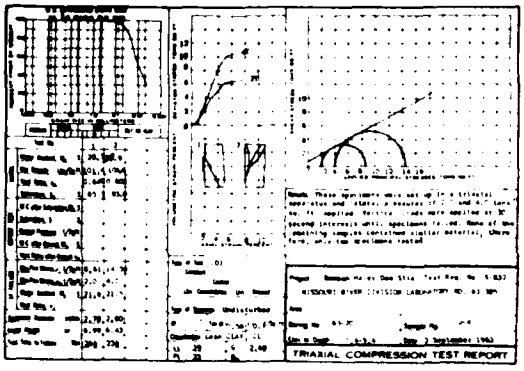


FIGURE 1

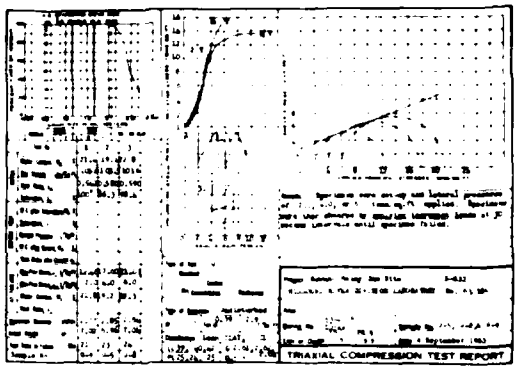


FIGURE 2

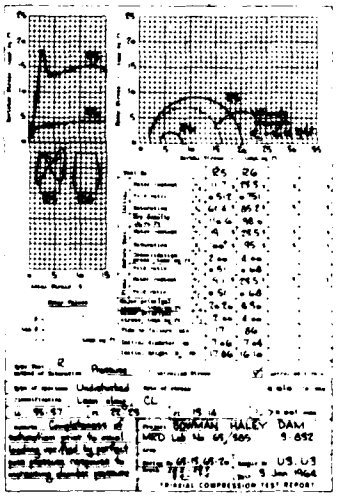


FIGURE 4

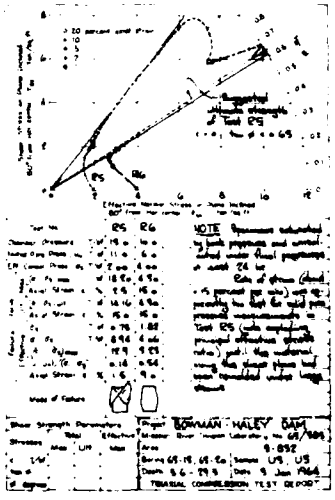


FIGURE 5

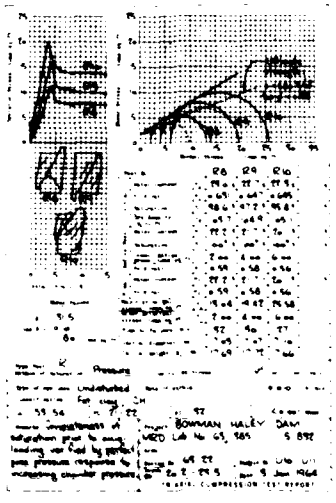
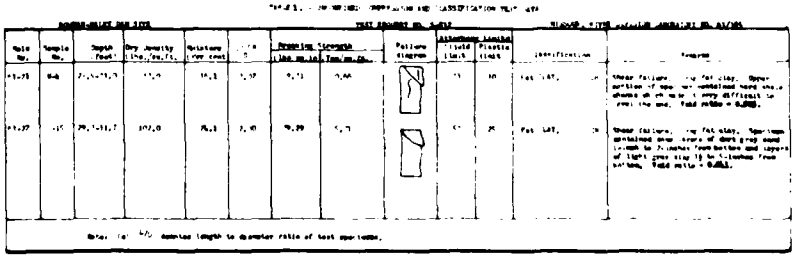
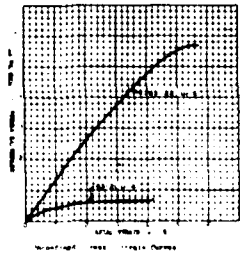
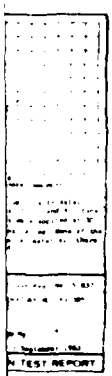


FIGURE 6





CONSTRUCTION F



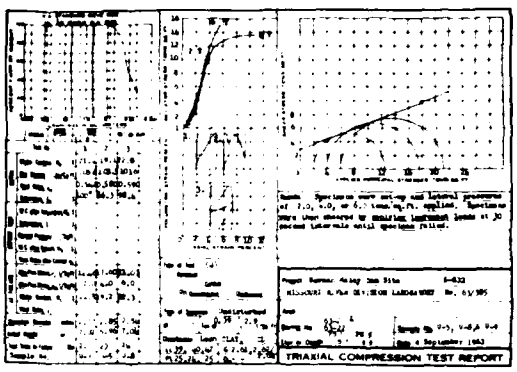


FIGURE 2

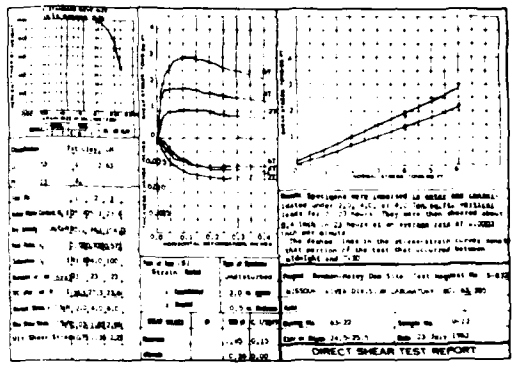


FIGURE 3

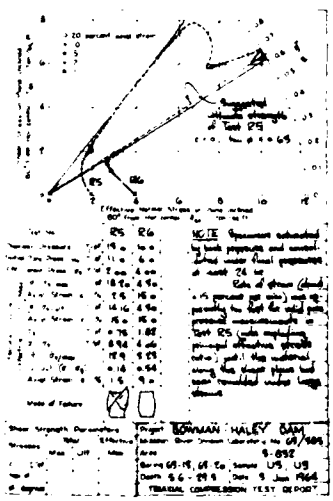


FIGURE 5

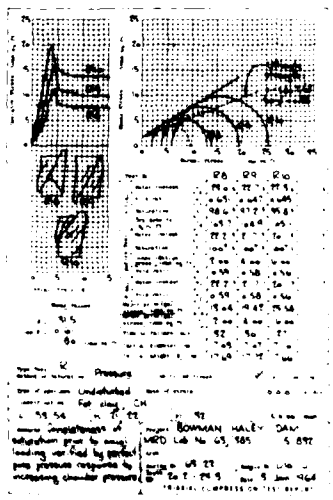


FIGURE 6

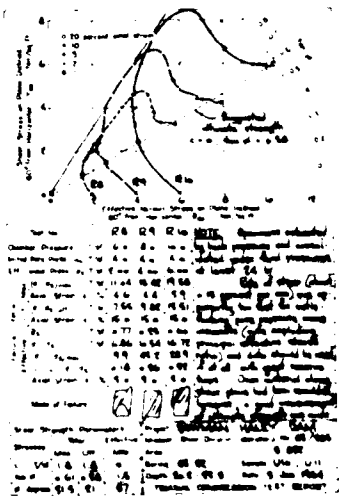
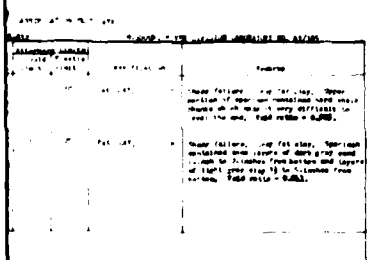
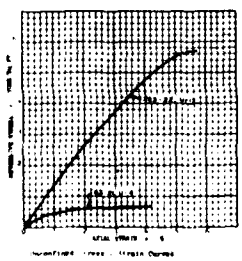


FIGURE 7





SAFETY PAYS

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER NORTH DAKOTA

BOWMAN-HALEY DAM & RESERVOIR

FOUNDATION SOIL TEST DATA
LEAN AND FAT CLAY (LUDLOW)

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 14

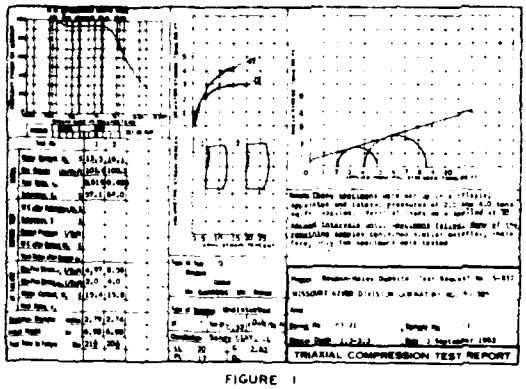


FIGURE 1

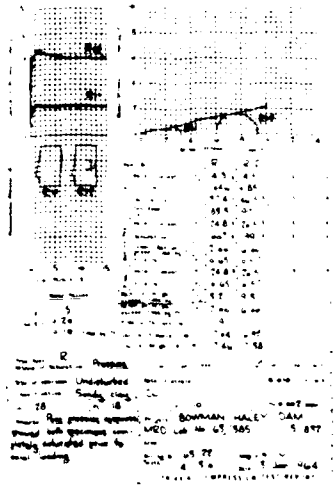


FIGURE 2

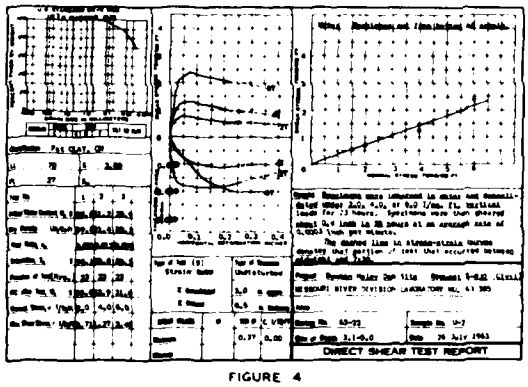
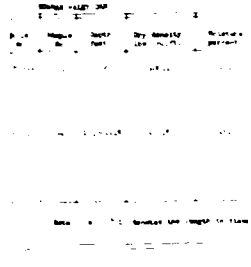
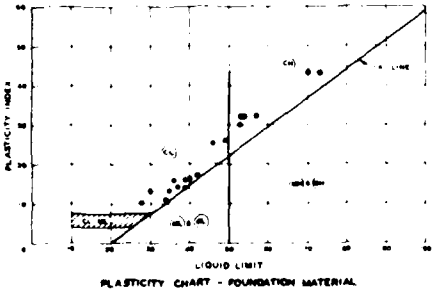


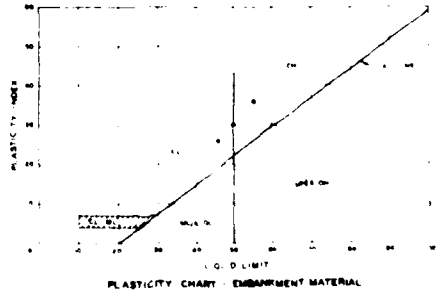
FIGURE 4





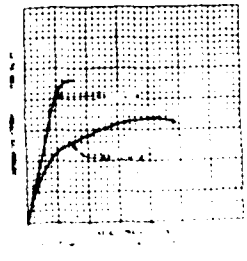
PLASTICITY CHART - FOUNDATION MATERIAL

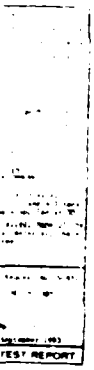
FIGURE 5



PLASTICITY CHART - EMBANKMENT MATERIAL

FIGURE 6





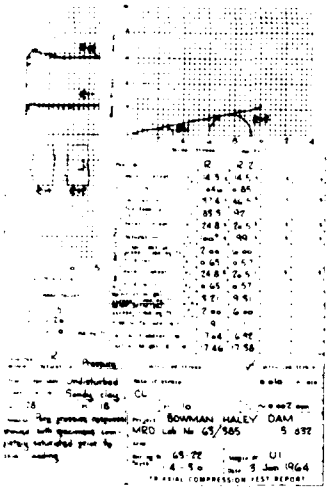


FIGURE 2

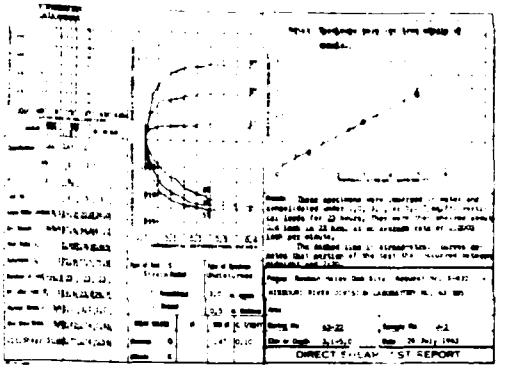
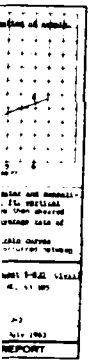
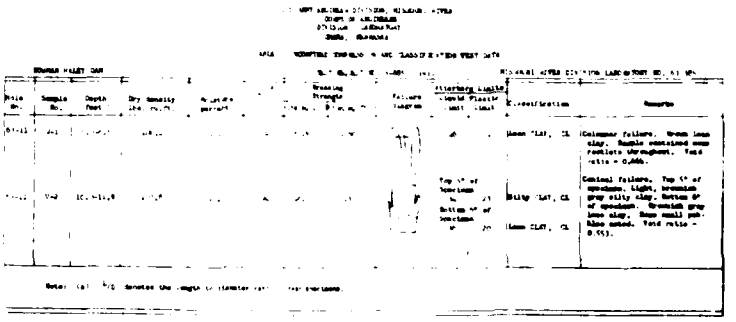
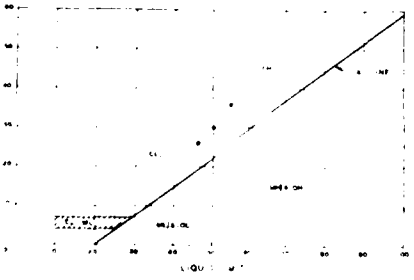


FIGURE 3

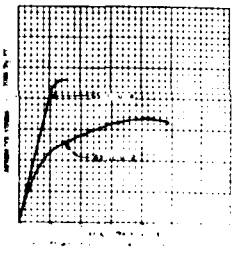






PLASTICITY CHART - EMBANKMENT MATERIAL

FIGURE 6



SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO. DA-56-000-
MODIFICATION NO

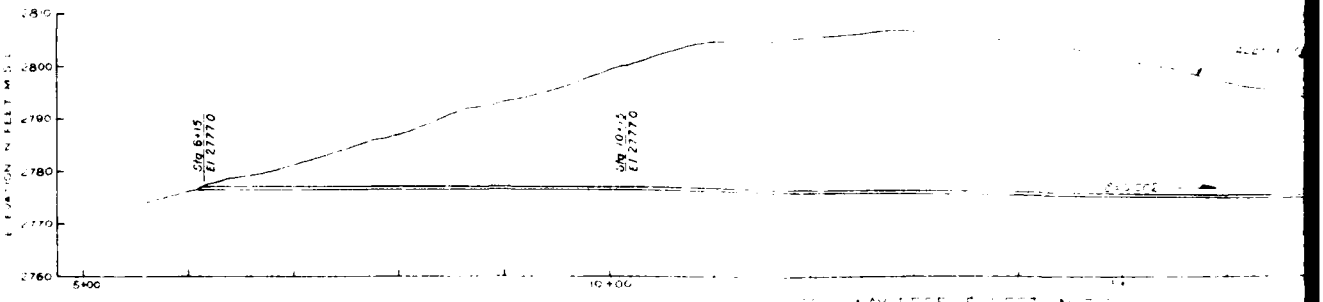
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

BOWMAN-HALEY DAM & RESERVOIR

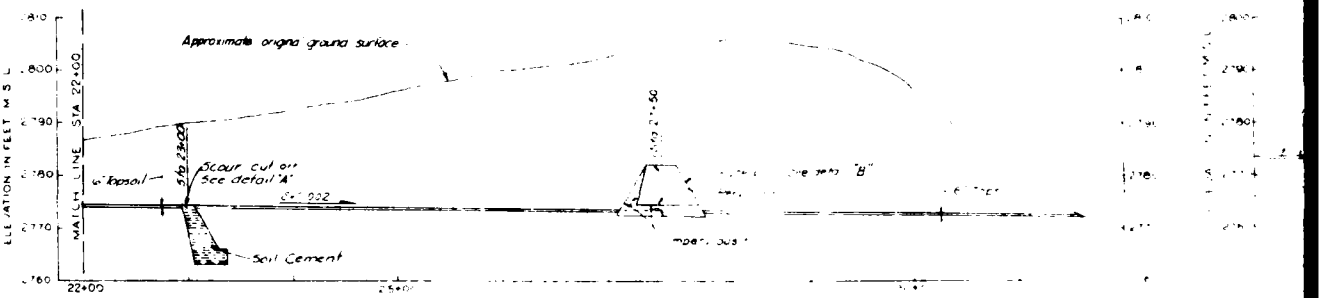
FOUNDATION SOIL TEST DATA
LEAN AND FAT CLAY (OVERBURDEN)
AND PLASTICITY CHARTS

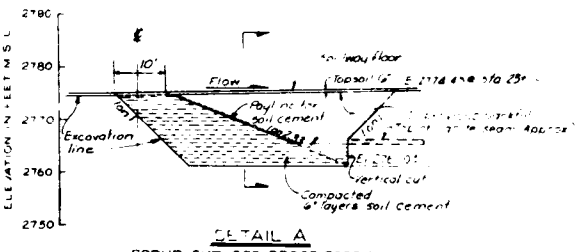
CORPS OF ENGINEERS



SPILLWAY PROFILE ALONG C

SCALE VERT. 1 INCH = 10 FEET
HOR. 1 INCH = 100 FEET

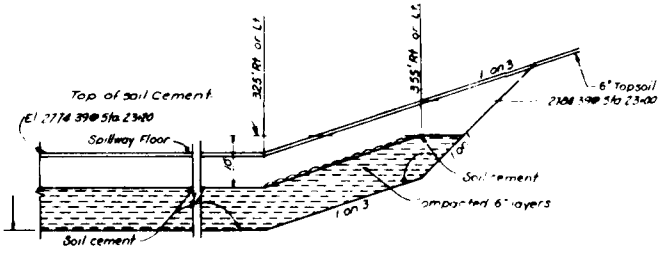




DETAIL A

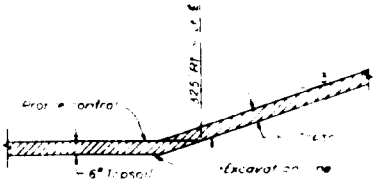
SCOUR CUT-OFF CROSS SECTION

SCALE 1 INCH = 10 FEET



SPILLWAY SIDE SLOPES AT SCOUR CUT-OFF CENTER LINE

SCALE 1 INCH = 10 FEET



DETAIL AT FLOOR OF SPILLWAY

SCALE 1 INCH = 1 FOOT



FLARE END SECTION

SCALE 1 INCH = 1

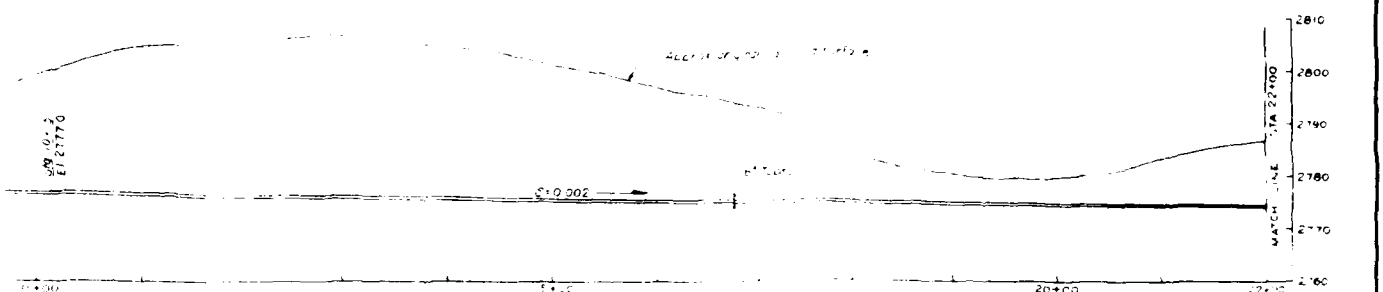
CONSTRU

A 105 Micro-master Film or a Paper Reproducible Record Copy Must Be Made Before Every Amendment and/or Modification

AMENDMENT DATE

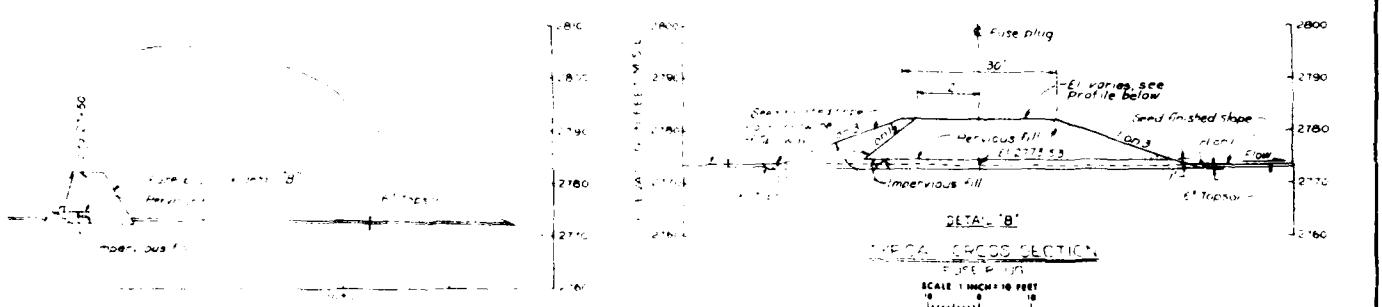
MODIFICATION DATE

U. S. ARMY



SPILLWAY PROFILE-SECTION 3-6

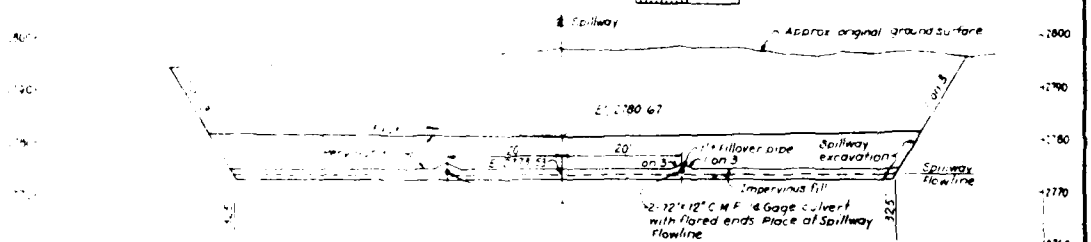
SCALE VERT. 1 INCH = 10 FEET
HORIZ. 1 INCH = 10 FEET



DETAIL "B"

TYPICAL CROSS SECTION
FUSE PLUG

SCALE 1 INCH = 10 FEET

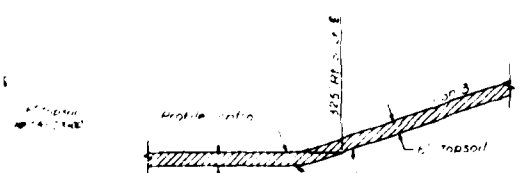


FUSE PLUG CHANNEL SECTION

SCALE 1 INCH = 50 FEET
1 INCH = 10 FEET

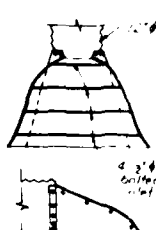
GENERAL NOTES:

1. All elevations shown refer to feet above M.S.L. 1929 General Adjustment



DETAIL AT FLOOR OF SPILLWAY

SCALE 1 INCH = 1 FOOT



FLARED END SECTION AND DETAIL

SCALE 1 INCH = 1 FOOT

THIS DRAWING HAS BEEN REDUCED TO THREE-FOURTHS THE ORIGINAL SCALE

Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

BOWMAN - HALEY DAM & RESERVOIR

DAM AND APPURTENANT WORKS

SPILLWAY PROFILE SECTIONS AND DETAILS

DESIGNED BY J R R
DRAWN BY B A
TRACED BY B A
CHECKED BY L J S
APPROVED
APPROVED
RECOMMENDED
APPROVED

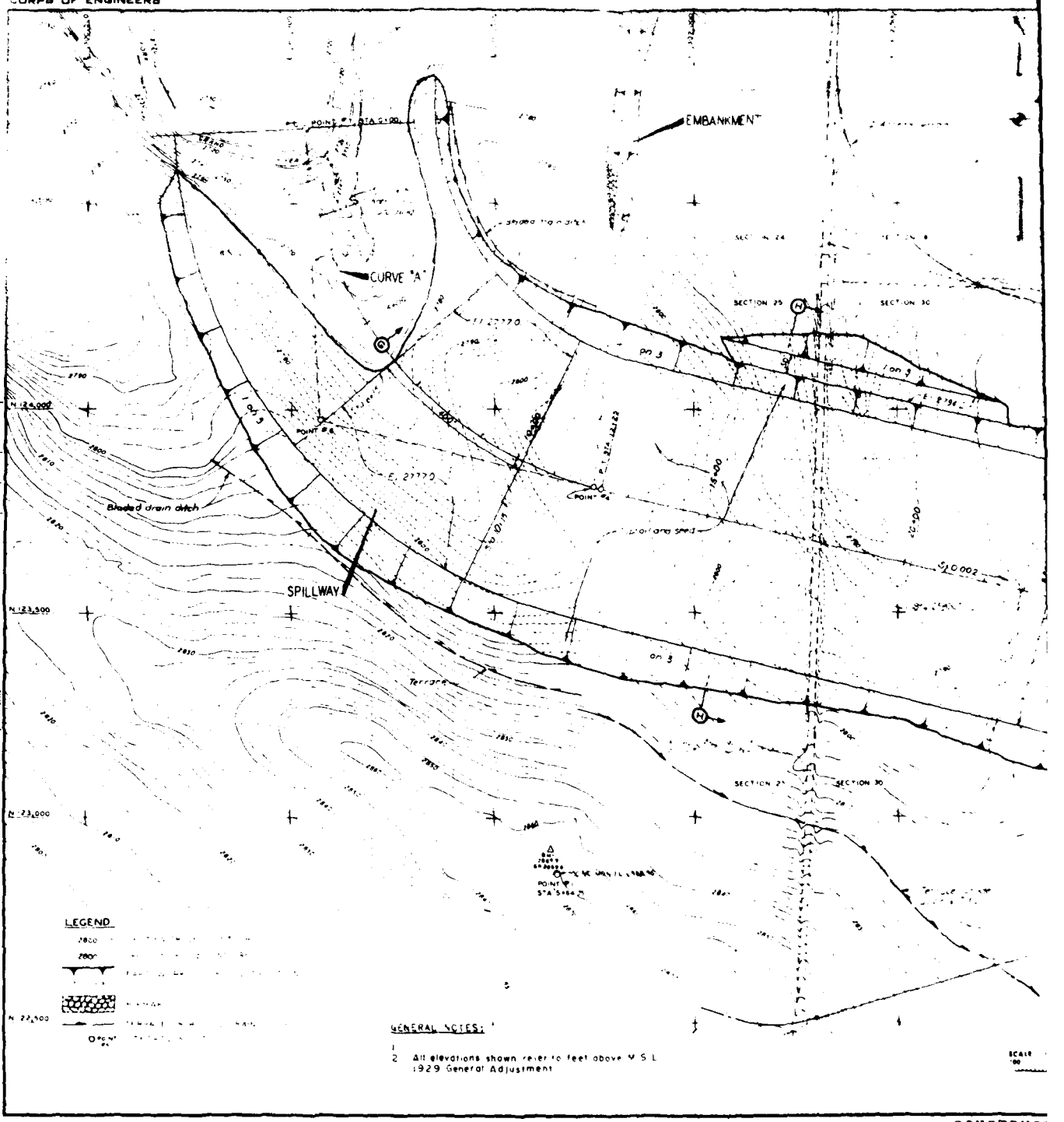
DATE APRIL 1982

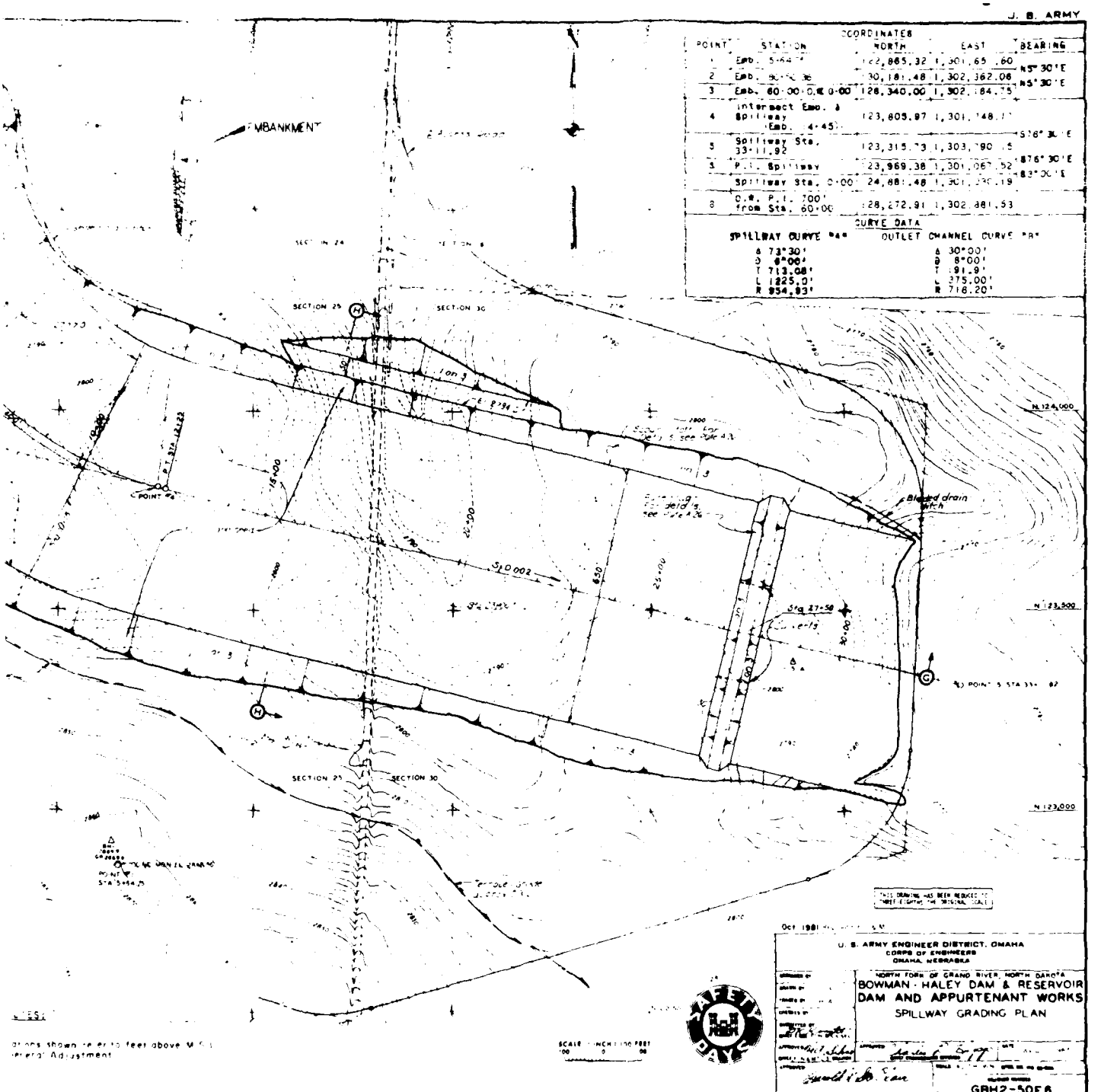
SCALE AS SHOWN

DRAWING NUMBER GBH2-SOE11

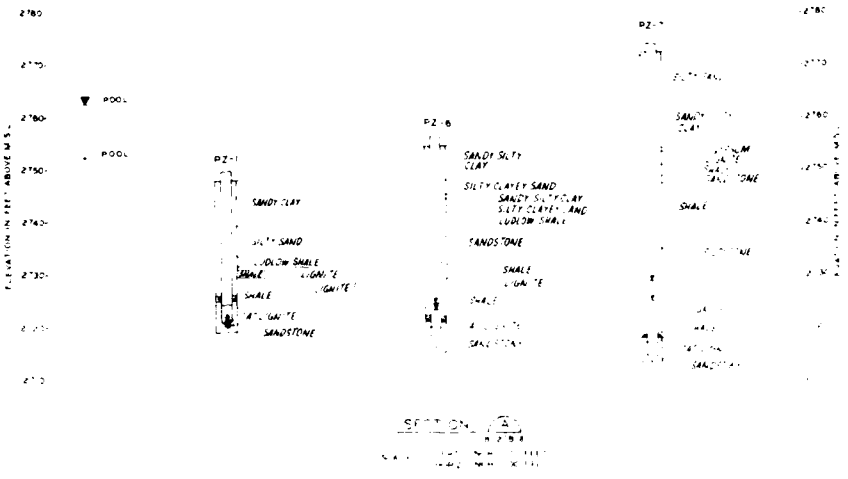
SAFETY PAYS

CORPS OF ENGINEERS

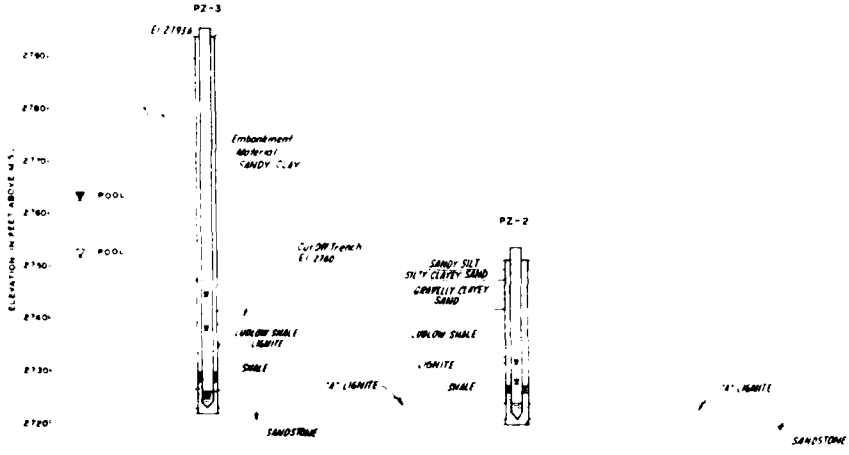

EMBANKMENT
CURVE "A"
SPILLWAY
Bladed drain ditch
Terrace
SECTION 25
SECTION 30
SECTION 29
SECTION 30
POINT "A"
POINT "B"
POINT "C"
POINT "D"
N 24,000
N 23,500
N 23,000
N 22,500
E 22770
E 23,324.42
E 23,324.42
E 23,324.42



CONSTRUCTION FOUNDATION REPORT (1985) PLATE 17



SECTION A



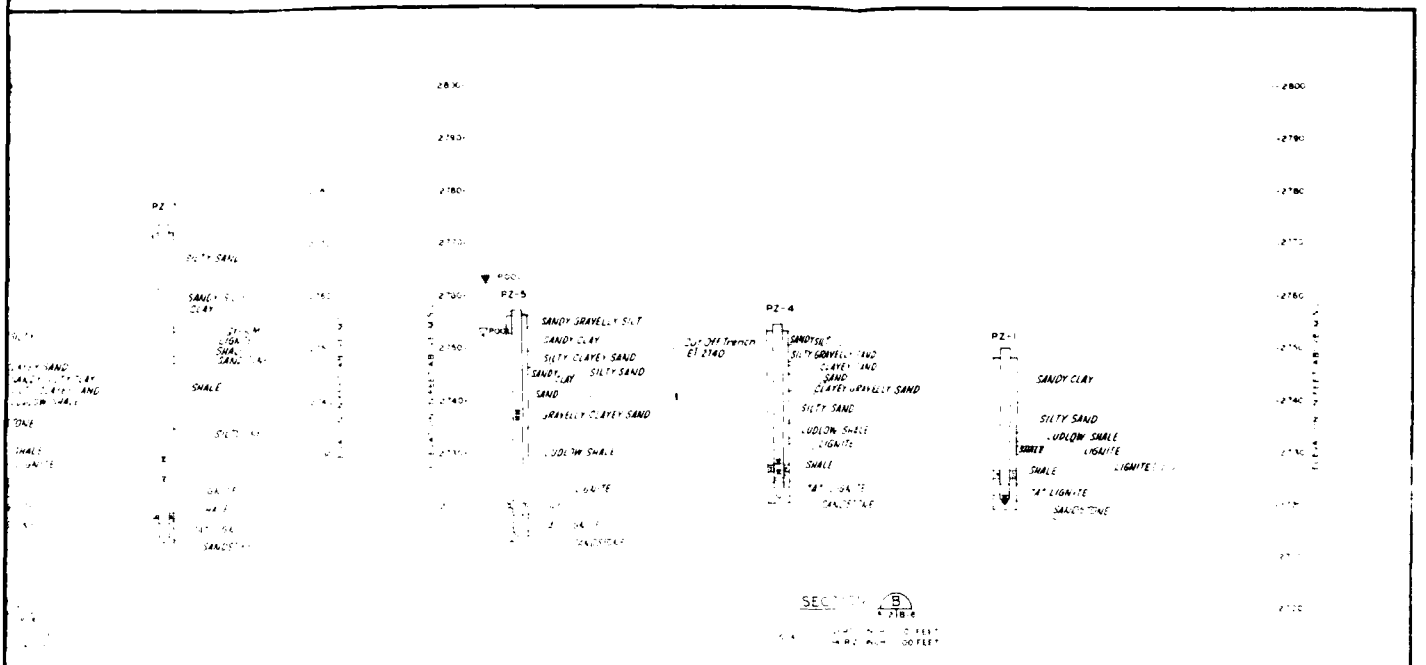
SECTION C

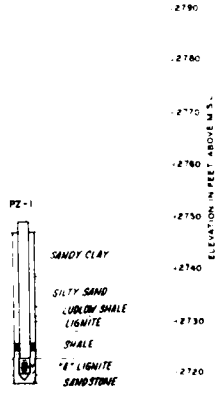
SCALE

PIEZOMETER DATA						
Piezometer No	Station	RD	Top Elevation of Piezometer	Tip Elevation	SENSING ZONE Top Elev	SENSING ZONE Bottom Elev
PZ 1	61+56	410 0'S	2769.7	2719.7	2728.4	2718.2
PZ 2	61+80	190 0'S	2753.0	2719.9	2729.0	2719.0
PZ 3	62+00	12 0'S	2796.1	2722.7	2727.1	2721.6
PZ 4	65+10	185 0'S	2755.3	2720.9	2729.8	2719.8
PZ 5	70+20	130 0'S	2758.8	2716.3	2719.7	2713.3
PZ 6	[illegible]	400 0'S	2757.1	2718.0	2729.0	2715.1
[illegible]	[illegible]	10 0'S	2754.6	2713.4	2718.4	2712.1

$$ - THINK VALUE ENGINEERING - $$

CONSTRUCTION FOR





LEGEND

- March 38 (Record High Pool)
- June 61 (Record Low Pool)

PIEZOMETER DATA

Piezometer No.	Station	RG	Top Elevation of Piezometer	Tip Elevation	SENSING ZONE Top Elev	SENSING ZONE Bottom Elev
PZ-1	61+56	410' D/S	2749.7	2719.7	2726.4	2718.2
PZ-2	61+80	150' D/S	2753.0	2719.9	2725.0	2719.0
PZ-3	62+00	12' U/S	2796.1	2722.7	2727.1	2721.6
PZ-4	65+10	145' D/S	2755.3	2720.9	2725.8	2719.8
PZ-5	70+20	130' U/S	2758.8	2714.3	2719.7	2711.9
PZ-6	59+54	400' D/S	2757.1	2718.0	2723.0	2715.3
PZ-7	59+55	30' D/S	2774.4	2713.4	2718.4	2712.1

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

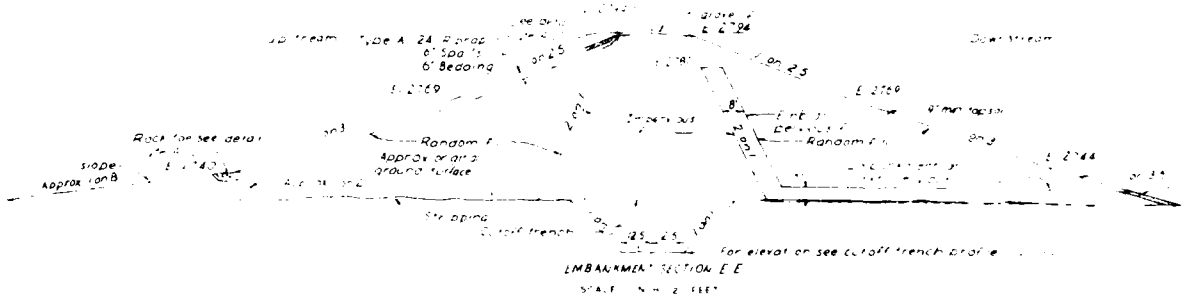
BOWMAN-HALEY DAM AND RESERVOIR

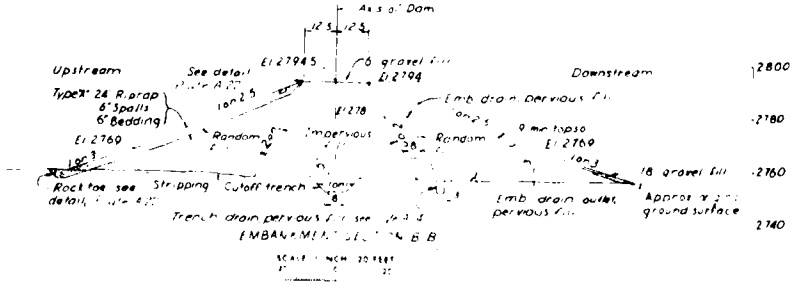
PIEZOMETER SECTIONS
"A" LIGNITE LAYER

THIS PLAN ACCOMPANIES CONTRACT NO. DACA45 MODIFICATION NO.

SAFETY PAYS

CORPS OF ENGINEERS





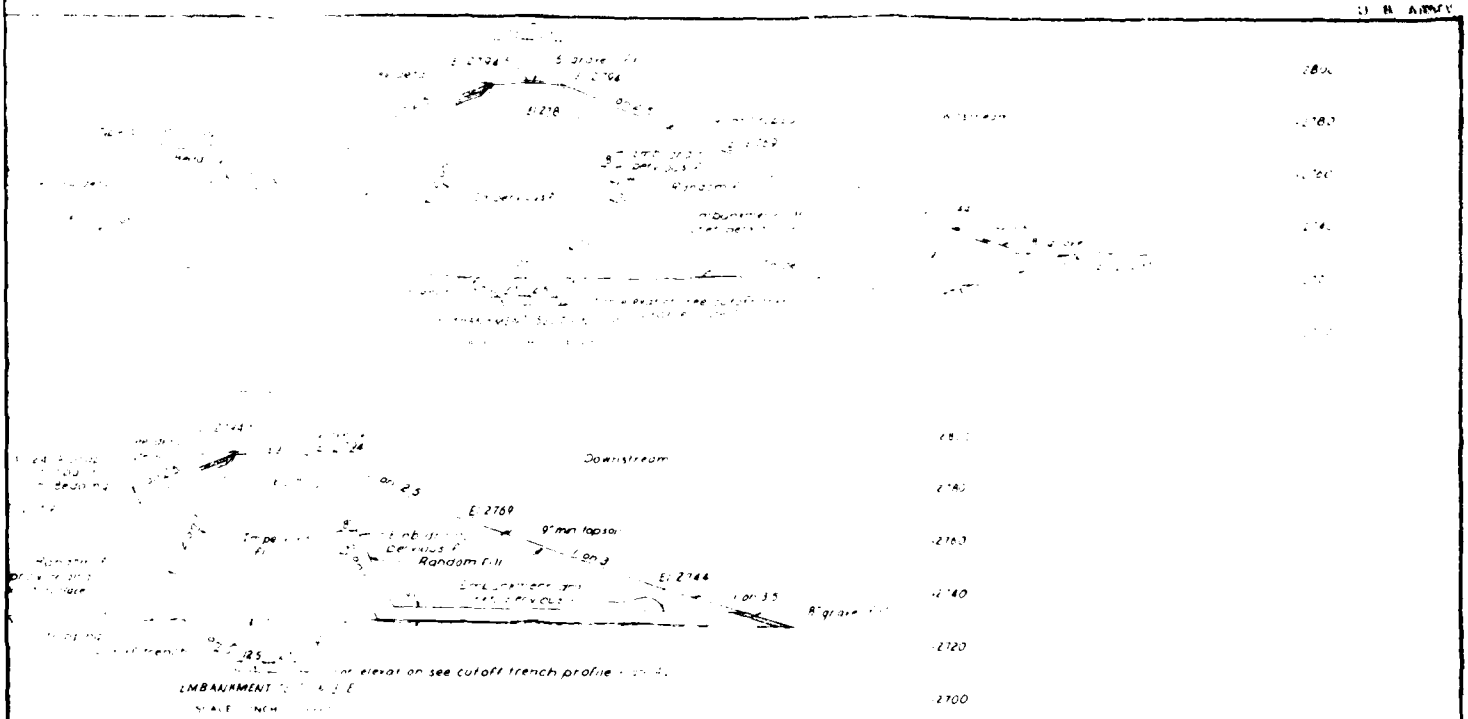
GENERAL NOTES

1.

2. All elevations shown refer to feet above N
1929 General Adjustment

3.

CONSTRUC



GENERAL NOTES

1

2 All elevations shown refer to feet above M S L. 1929 General Adjustment

3

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTS THE ORIGINAL SCALE

Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN - HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
EMBANKMENT SECTIONS

APPROVED Donald Wilson Clare
CHIEF, ENGINEERING DIVISION

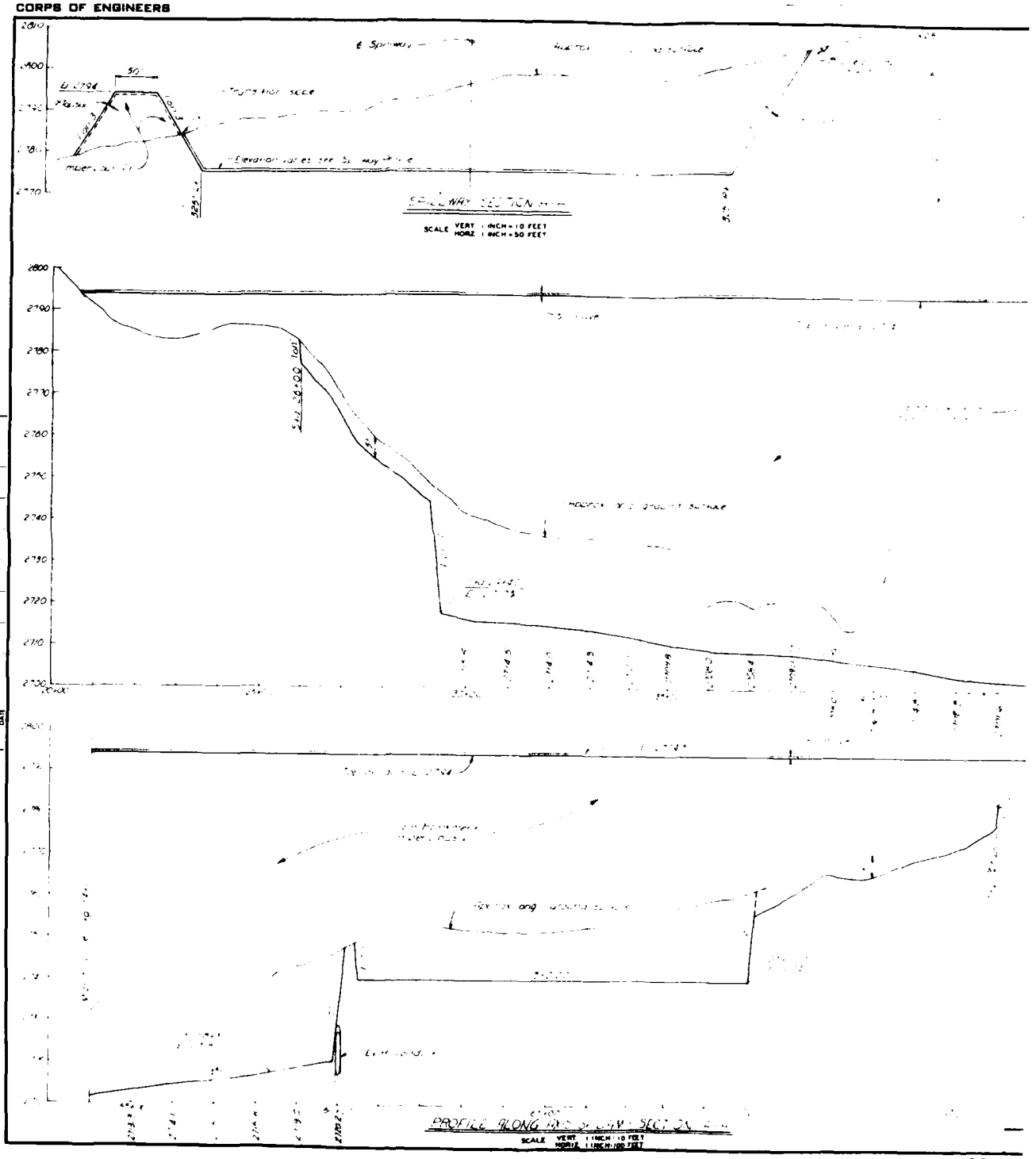
DATE APRIL 1968

SCALE AS SHOWN

DRAWING NO. GBH 2-50 E 8

SAFETY PAYS

CORPS OF ENGINEERS

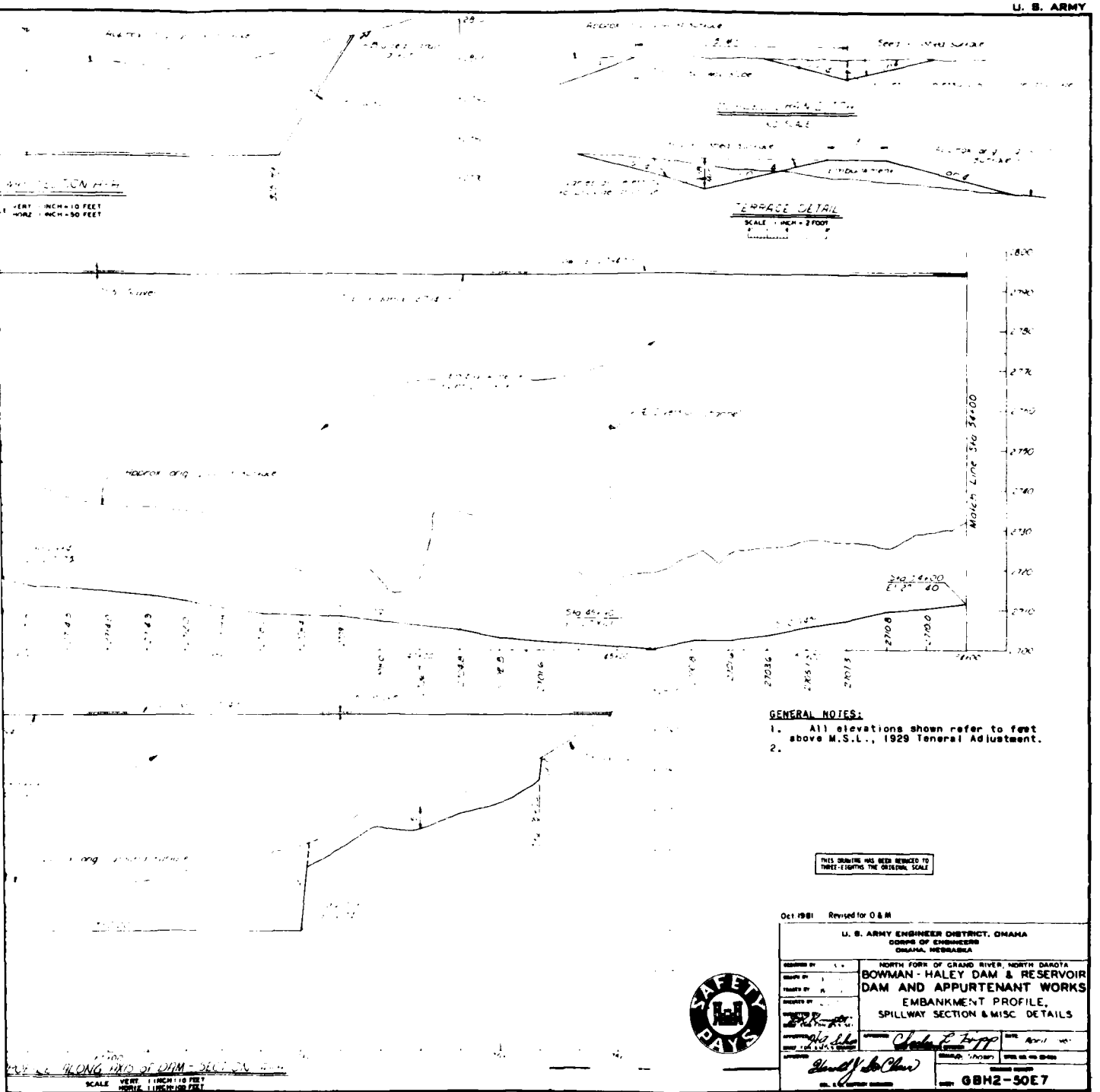


A 105 Micromaster Film or a Paper Reproducible Record Copy Must Be Made Before Every Amendment and/or Modification

AMENDMENT	
DATE	
MODIFICATION	
DATE	

CONST

U. S. ARMY



GENERAL NOTES:

1. All elevations shown refer to feet above M.S.L., 1929 General Adjustment.
2.

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN - HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
EMBANKMENT PROFILE,
SPILLWAY SECTION & MISC DETAILS

APPROVED Charles L. Tripp DATE April 1982

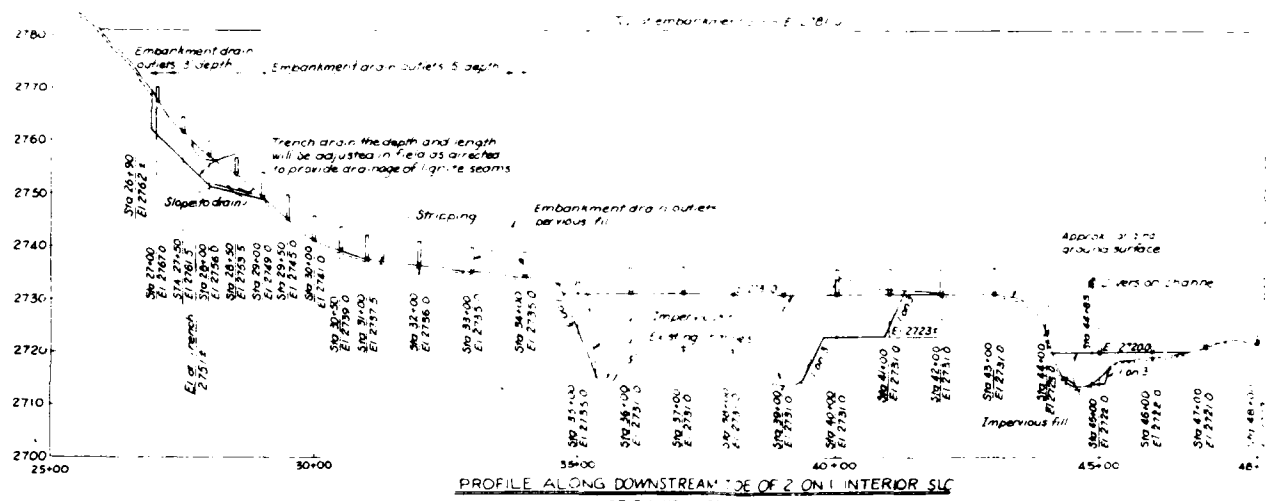
RECOMMENDED Harold J. McClure

DRAWING NO. GBH2-50E7

SAFETY PAYS

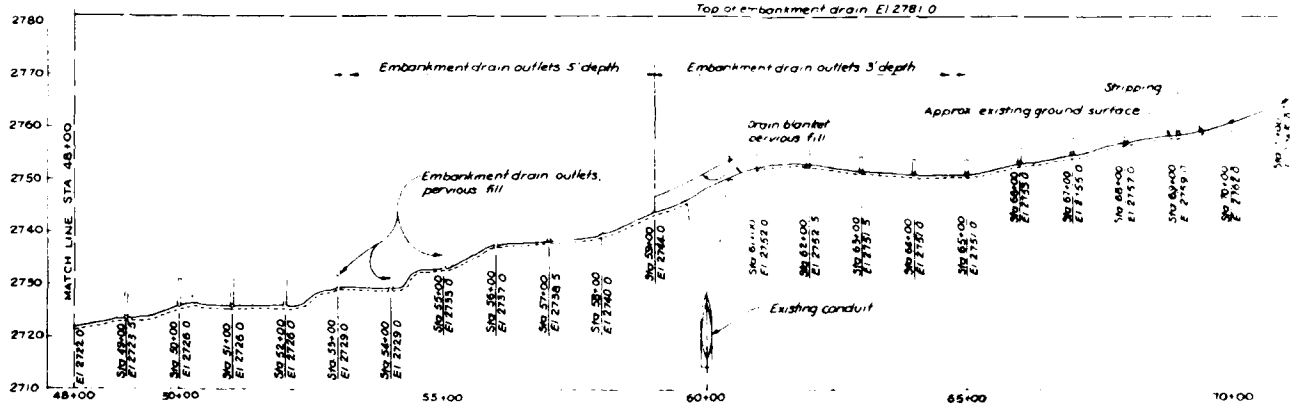
CONSTRUCTION FOUNDATION REPORT (1985) PLATE 20

CORPS OF ENGINEERS

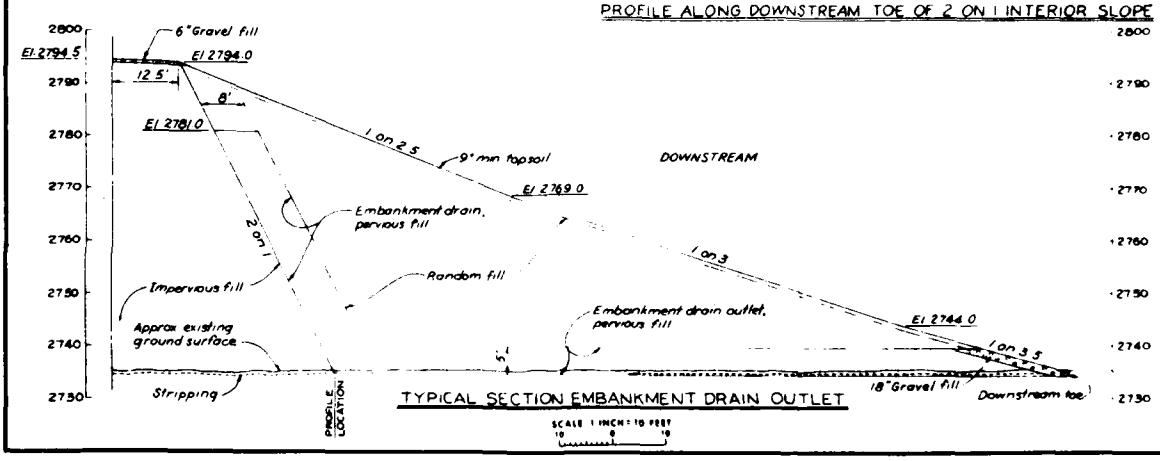


PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLO

SCALE HORIZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE

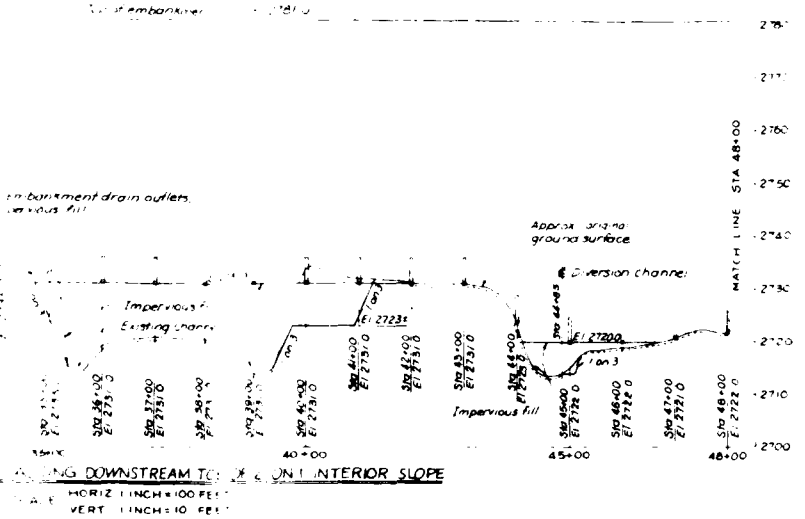


TYPICAL SECTION EMBANKMENT DRAIN OUTLET

SCALE 1 INCH = 10 FEET

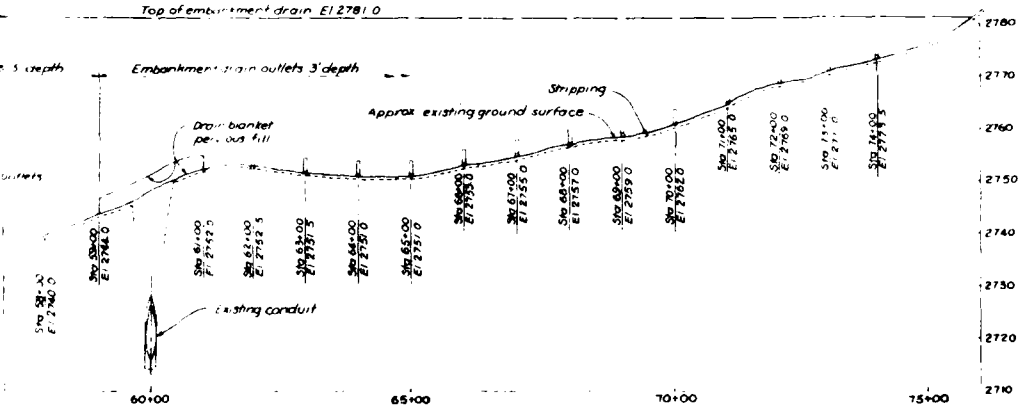
CONSTR

U. S. ARMY

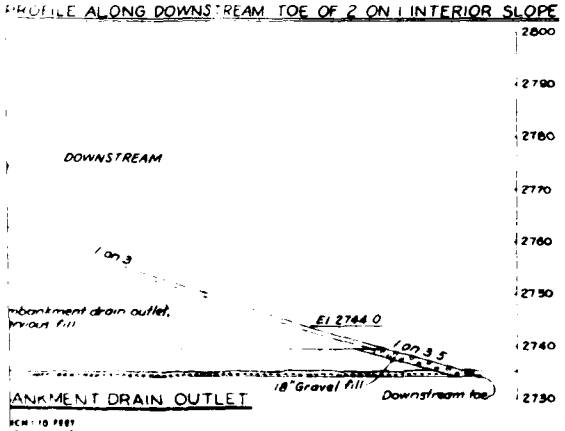


PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE

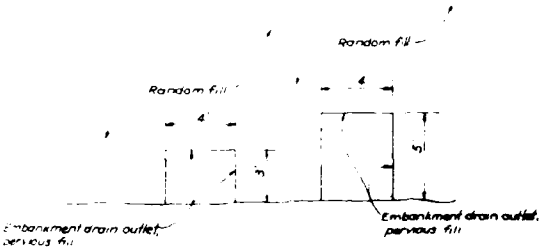
HORIZ 1 INCH = 100 FEET
VERT 1 INCH = 10 FEET



PROFILE ALONG DOWNSTREAM TOE OF 2 ON 1 INTERIOR SLOPE



ANKMENT DRAIN OUTLET



TYPICAL EMBANKMENT DRAIN OUTLET

GENERAL NOTES:

1. All elevation shown refer to feet above M.S.L. 1929, General Adjustment.

THIS DRAWING WAS REDUCED TO THREE-FOURTHS THE ORIGINAL SCALE

THIS DRAWING HAS BEEN REDUCED TO THREE-FOURTHS THE ORIGINAL SCALE

SAFETY PAYS

Oct 1981 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

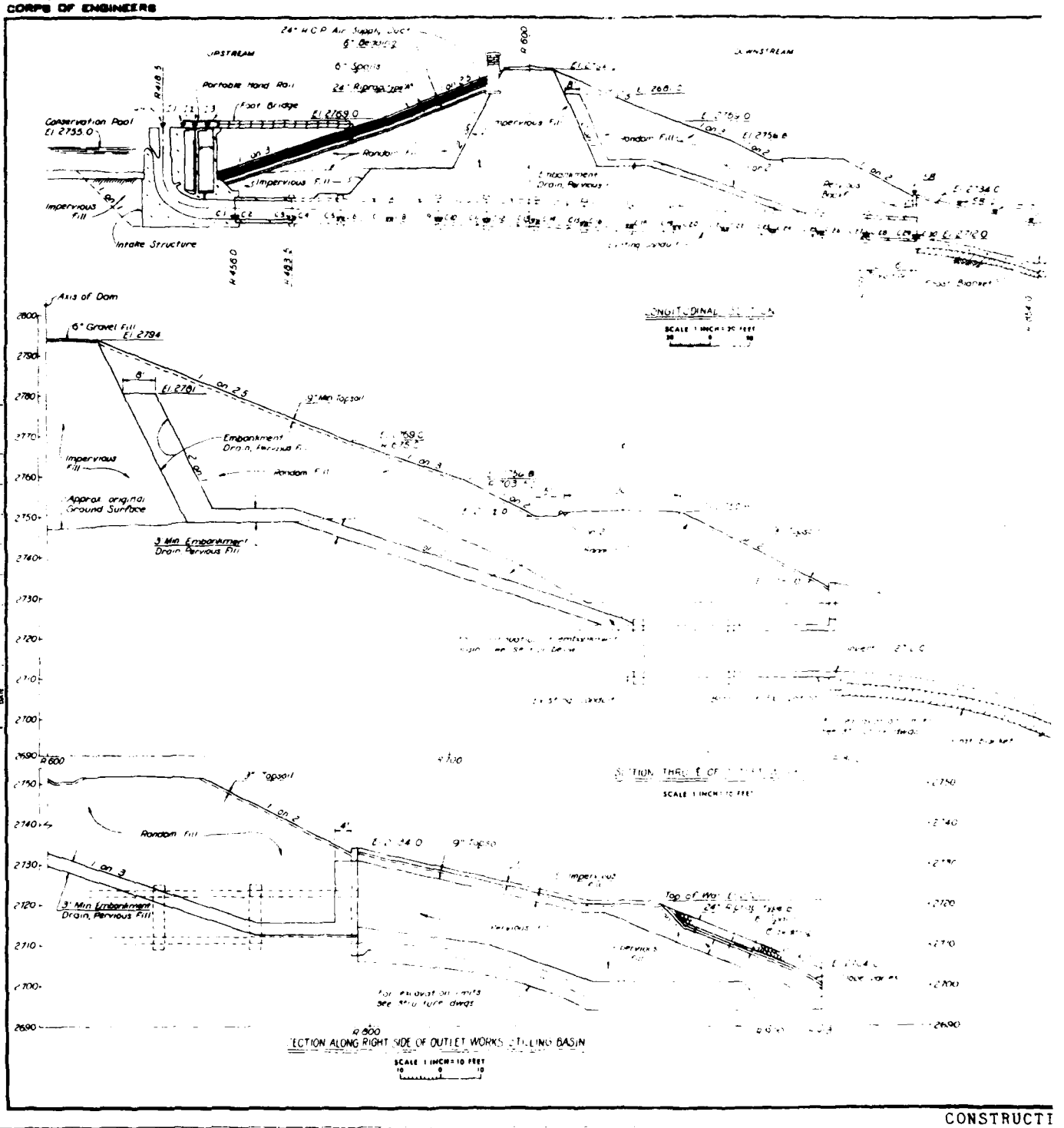
NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN - HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
EMBANKMENT DRAIN
PROFILE, SECTION AND DETAIL

APRIL 1968

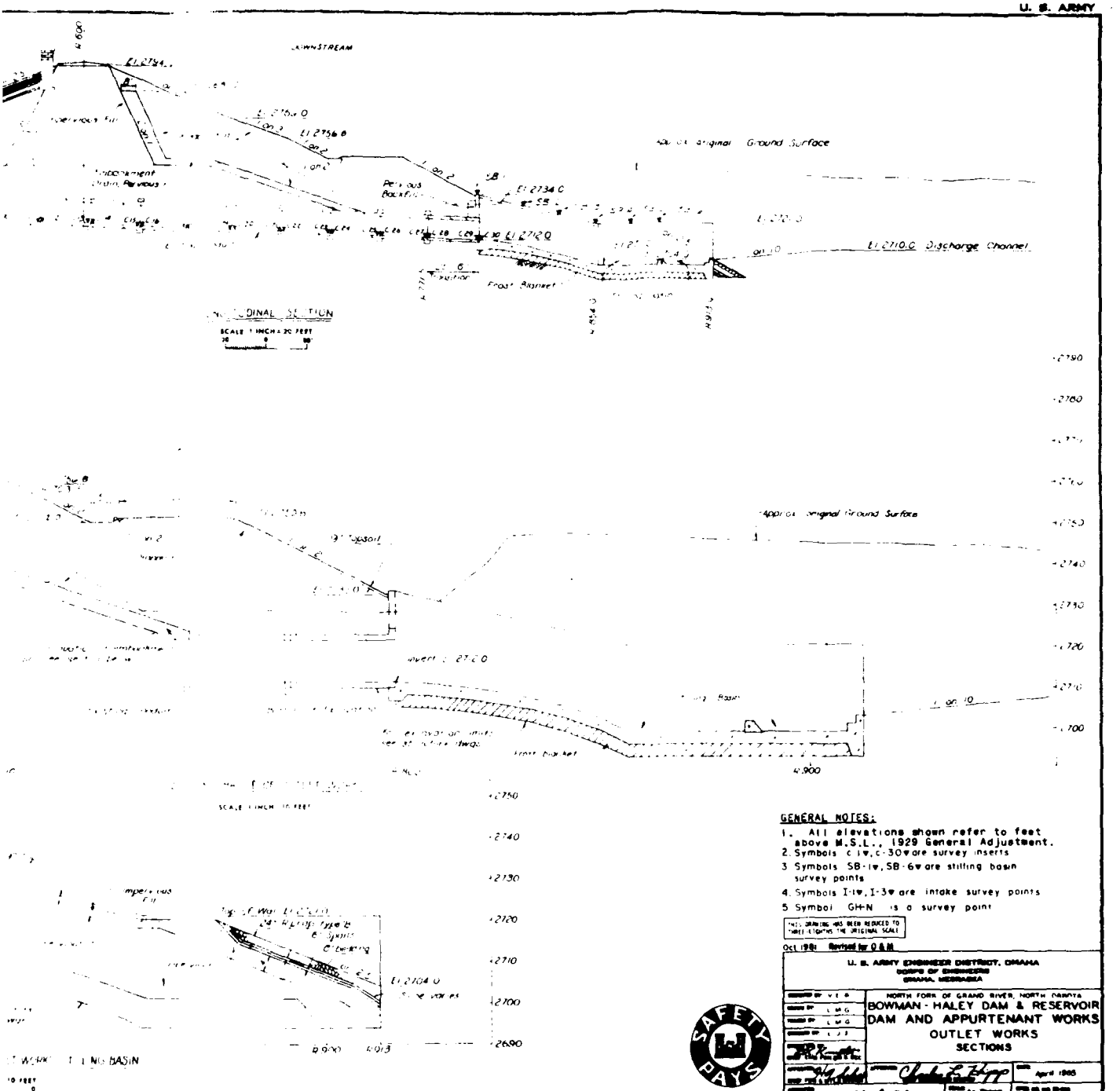
GBH2-5059

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 21

CORPS OF ENGINEERS



CONSTRUCTI



GENERAL NOTES:

1. All elevations shown refer to feet above M.S.L., 1929 General Adjustment.
2. Symbols C-1▼, C-3▼ are survey inserts
3. Symbols SB-1▼, SB-6▼ are stilling basin survey points
4. Symbols I-1▼, I-3▼ are intake survey points
5. Symbol GH-N is a survey point

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

Oct 1984 Revised for O & M

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

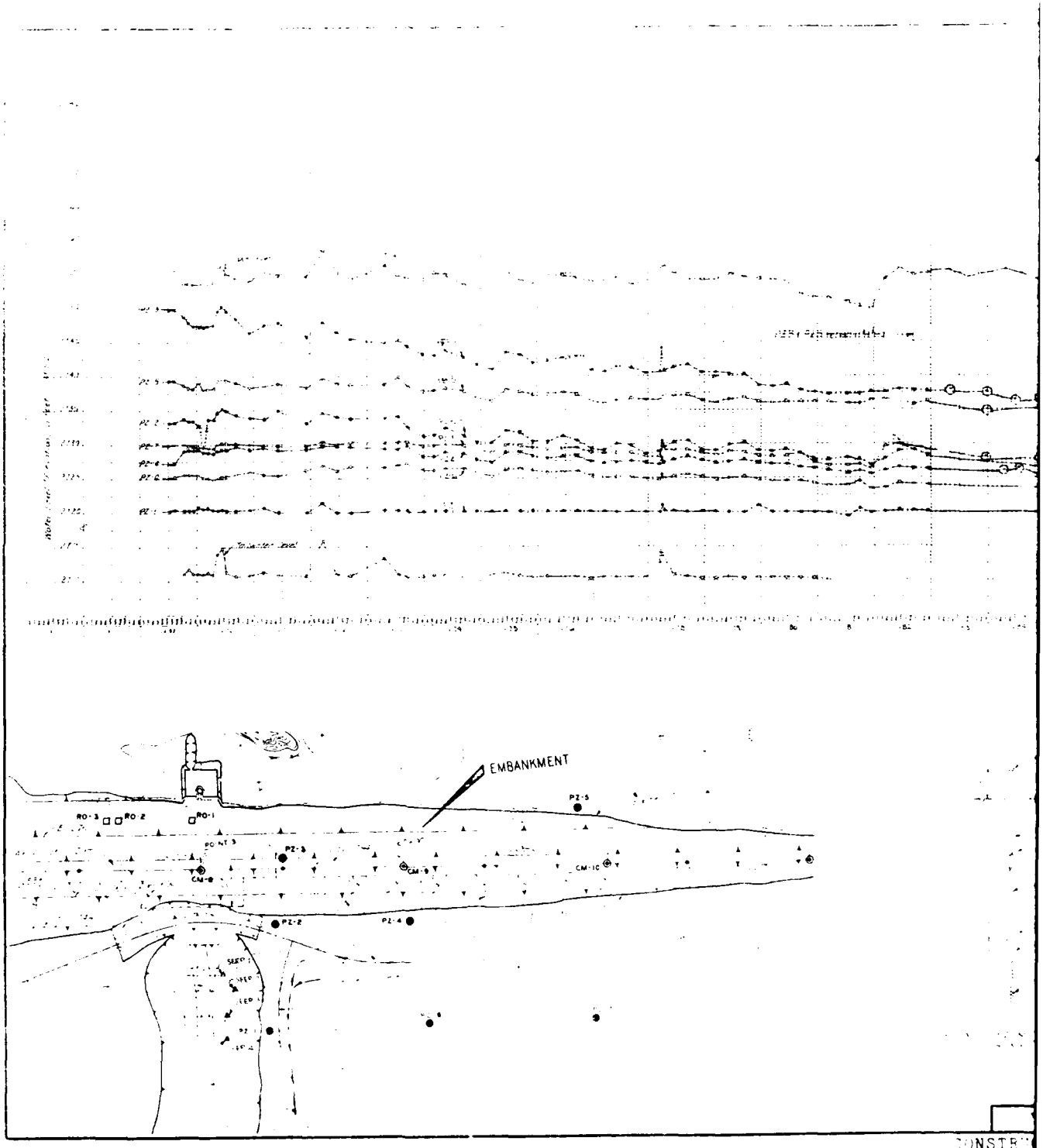
BOWMAN - HALEY DAM & RESERVOIR
DAM AND APPURTENANT WORKS
OUTLET WORKS
SECTIONS

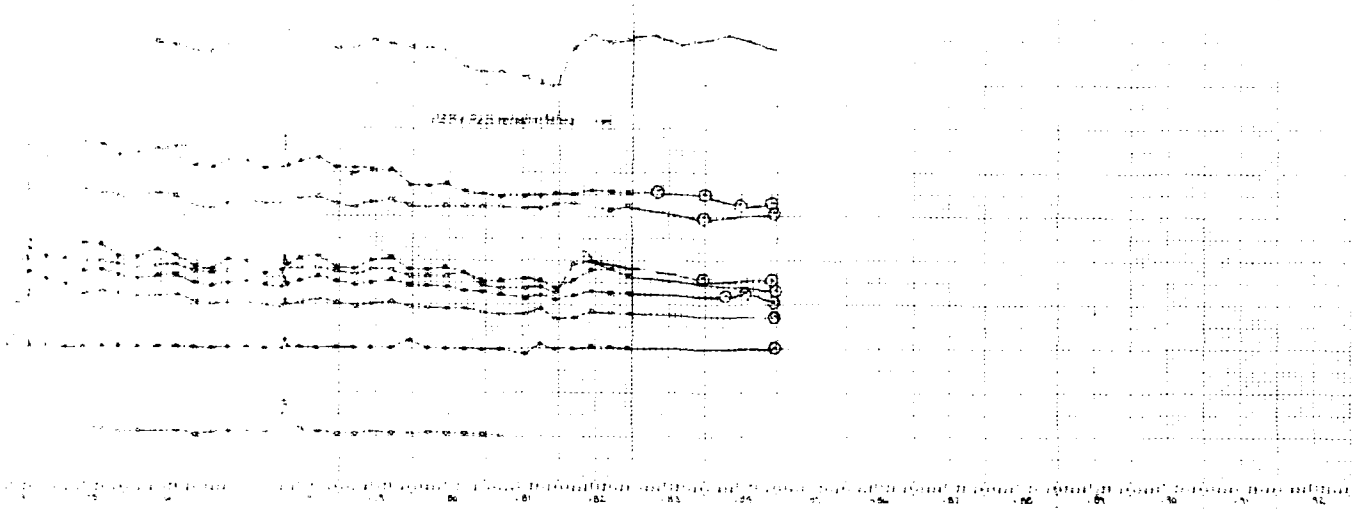
April 1985

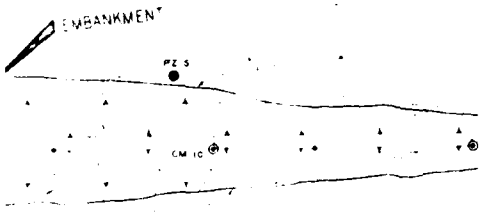
GBH2-50E17

SAFETY PAYS

CONSTRUCTION FOUNDATION REPORT (1985) PLATE 22


EMBANKMENT
RO-3
RO-2
RO-1
POINT 3
PZ-3
PZ-5
PZ-2
PZ-4
CM-1C
SEEP
SEEP
SEEP
PZ
SEEP





U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA

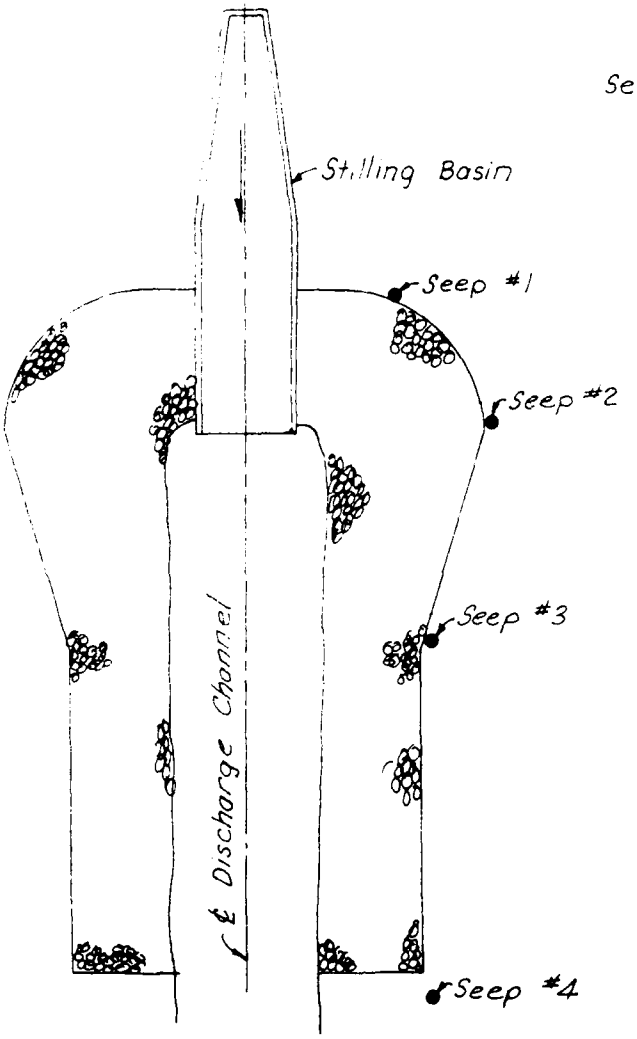
BOWMAN-HALEY DAM AND RESERVOIR

PIEZOMETER OBSERVATIONS

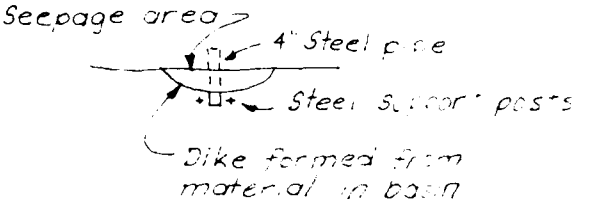
"A" LIGNITE LAYER

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO

SAFETY PAYS



SEEPAGE AREA LOCATION PLAN



PLAN- SEEPAGE MEASUREMENT STATION

4" Steel pip

Steel sup[illegible] posts

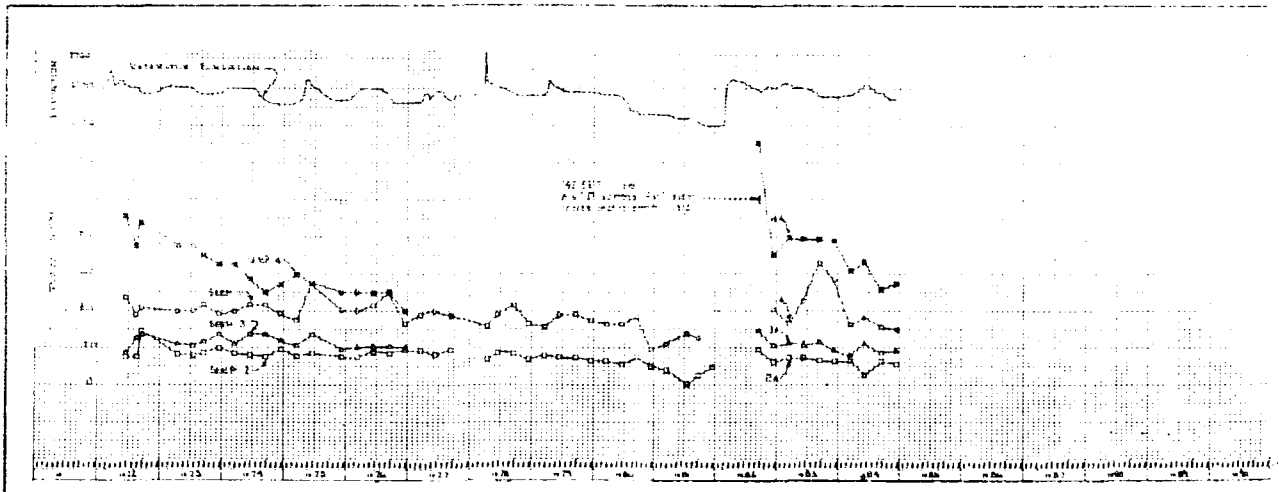
[illegible] formed fro[illegible]
[illegible]rial in bas[illegible]

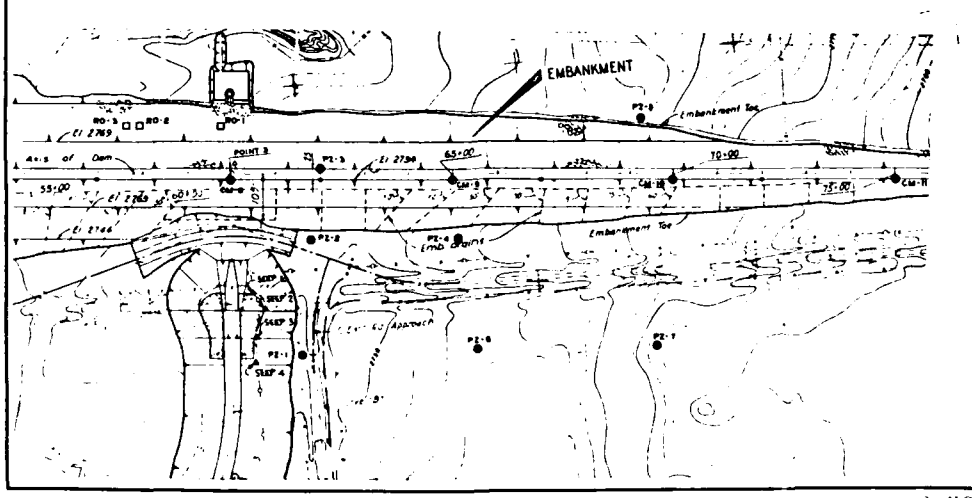
SEEPAGE MEASUREMENT
[illegible]TATION

DATE	FLOW G.P.M.					HEADWATER	TAILWATER
	SEEP #1	SEEP #2	SEEP #3	SEEP #4	TOTAL FLOW	ELEV	ELEV
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
29 JUN 1972	4.7	1.5	1.7	9.1	17.0	2755.83	2702.68
10 AUG '72	3.8	1.5	2.5	7.5	15.3	55.10	1.0

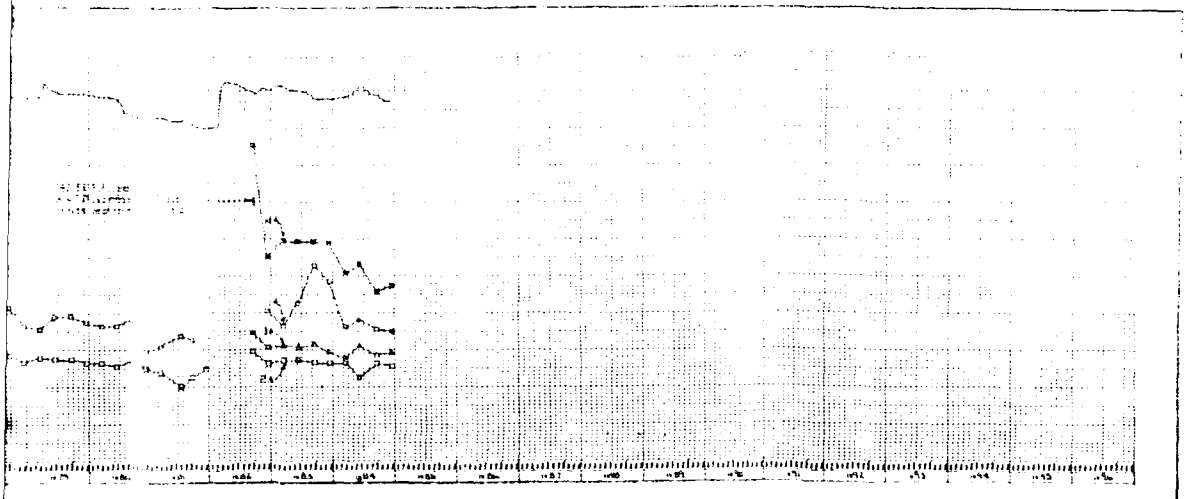
BOWMAN-HALEY DAM AND LAKE

SEEPAGE ALONG LIGNITE SEEMS
LEFT BANK DISCHARGE CHANNEL

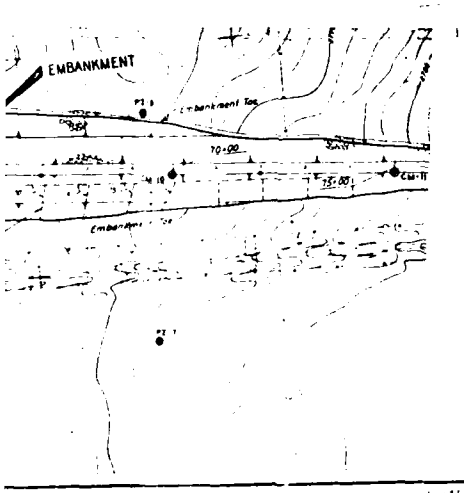




CONSTRUCTION FOUNDATION



Note: 1 Seep No 3 & 4 dry in August
Last reading Dec 1976
2 Seep No 2, no flow to read
August 1973 and April 1974



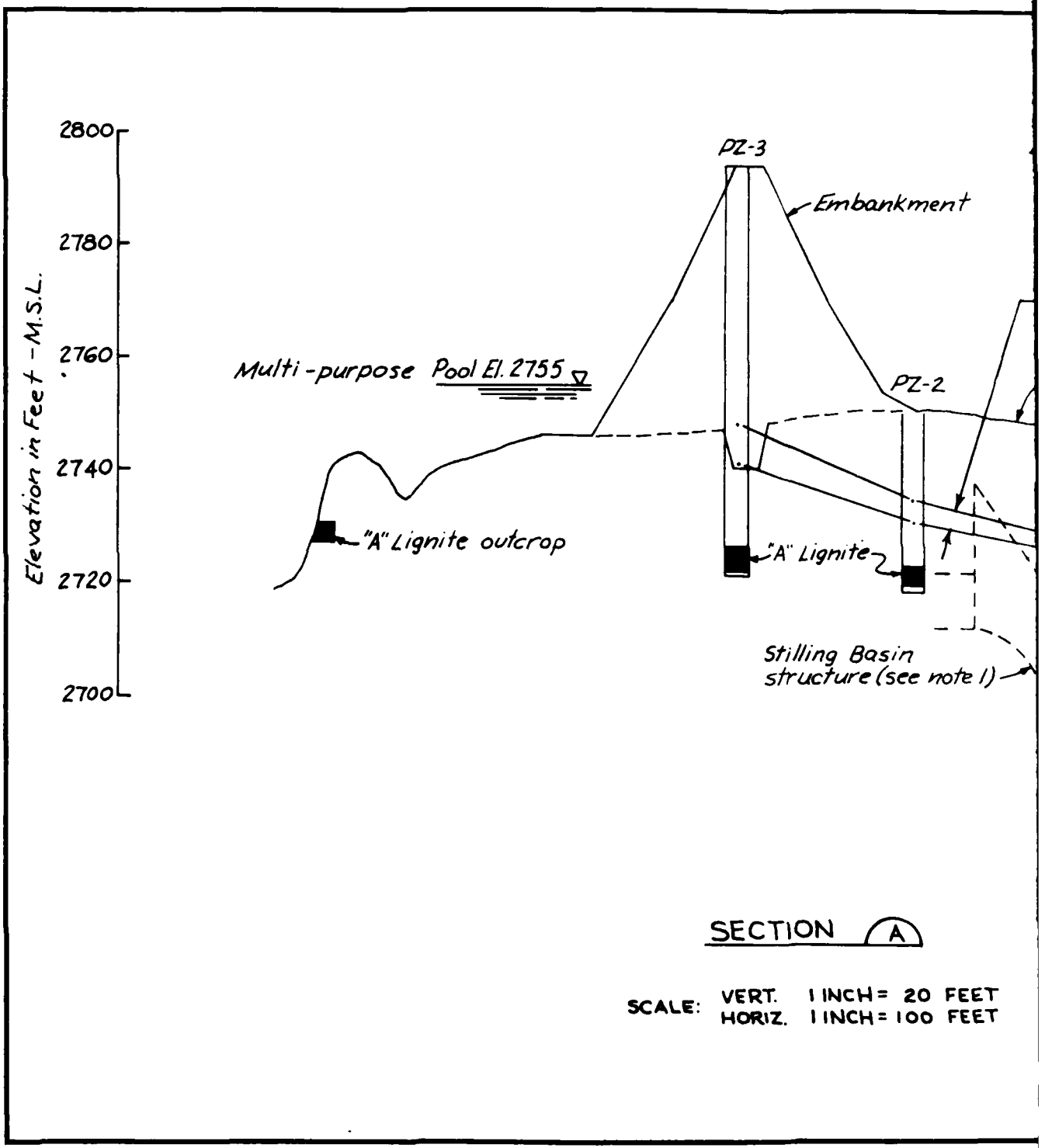
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM AND RESERVOIR

SEEPAGE ALONG LIGNITE SEAMS
LEFT BANK DISCHARGE CHANNEL
FLOW OBSERVATIONS

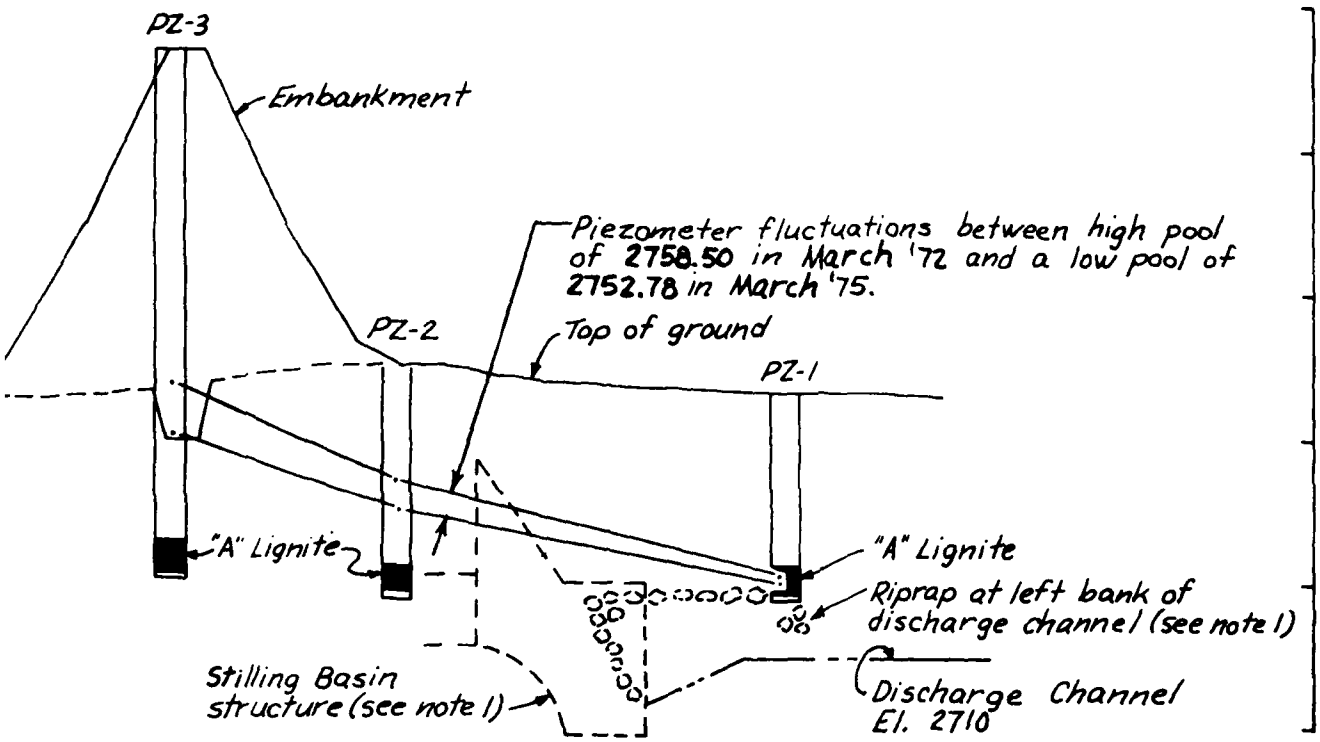
SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.



SECTION (A)

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET



Notes:

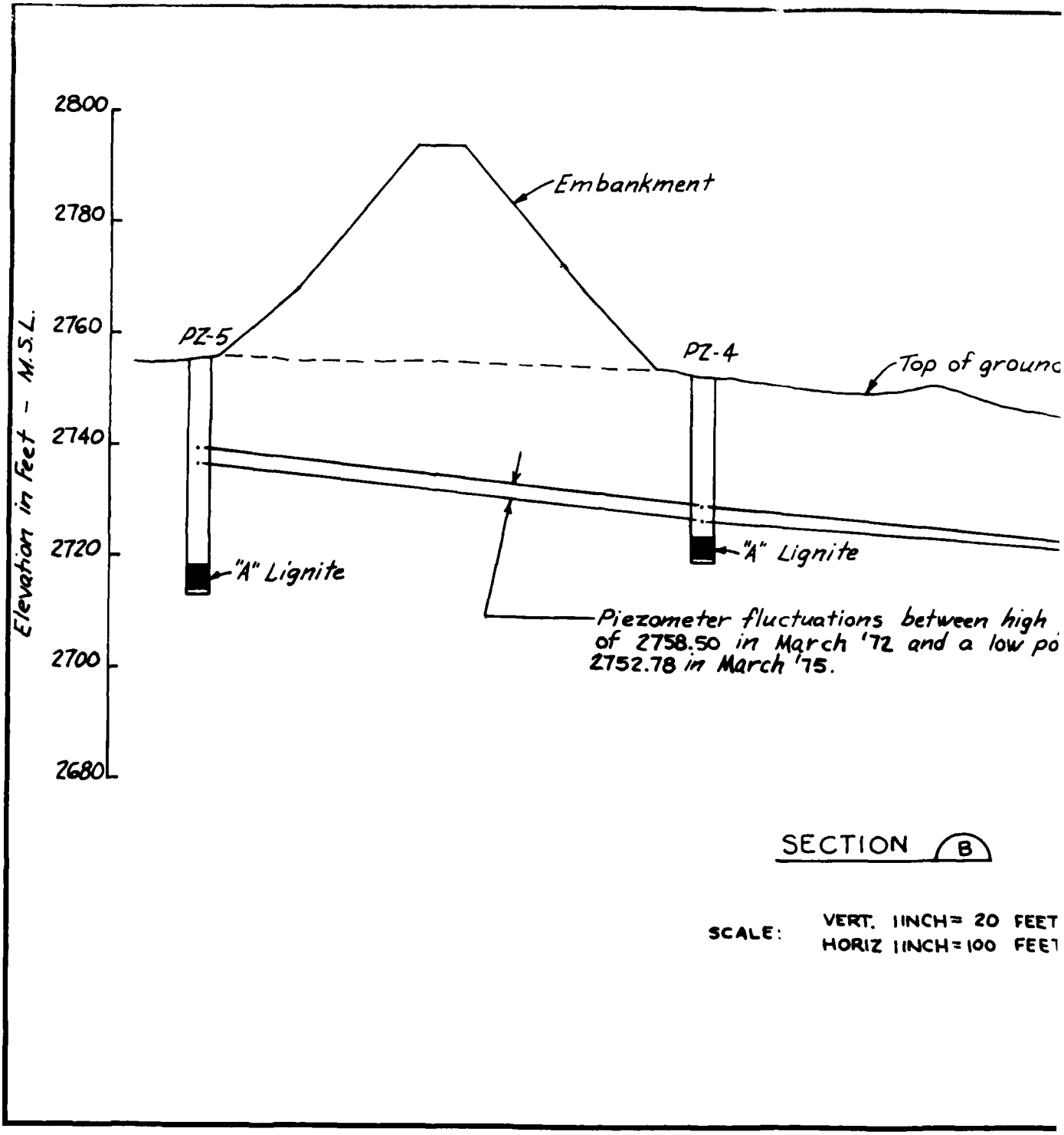
1. The stilling basin structure is located approx. 150' south of Section "A"
2. Seepage is emerging along the upper edge of the riprap, at the exposed "A" Lignite seam.

SECTION (A)

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET

BOWMAN-HALEY DAM AND LAKE

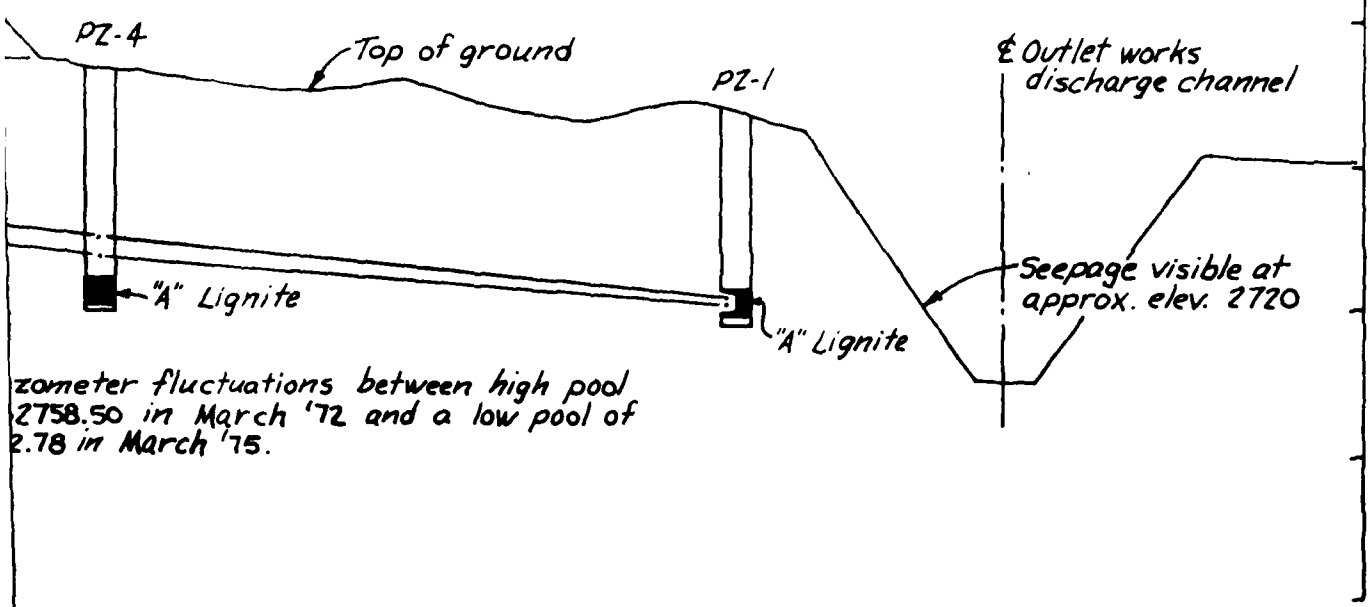
PIEZOMETERS
SECTION "A"



SECTION (B)

SCALE: VERT. 1INCH= 20 FEET
HORIZ 1INCH=100 FEET

nkment



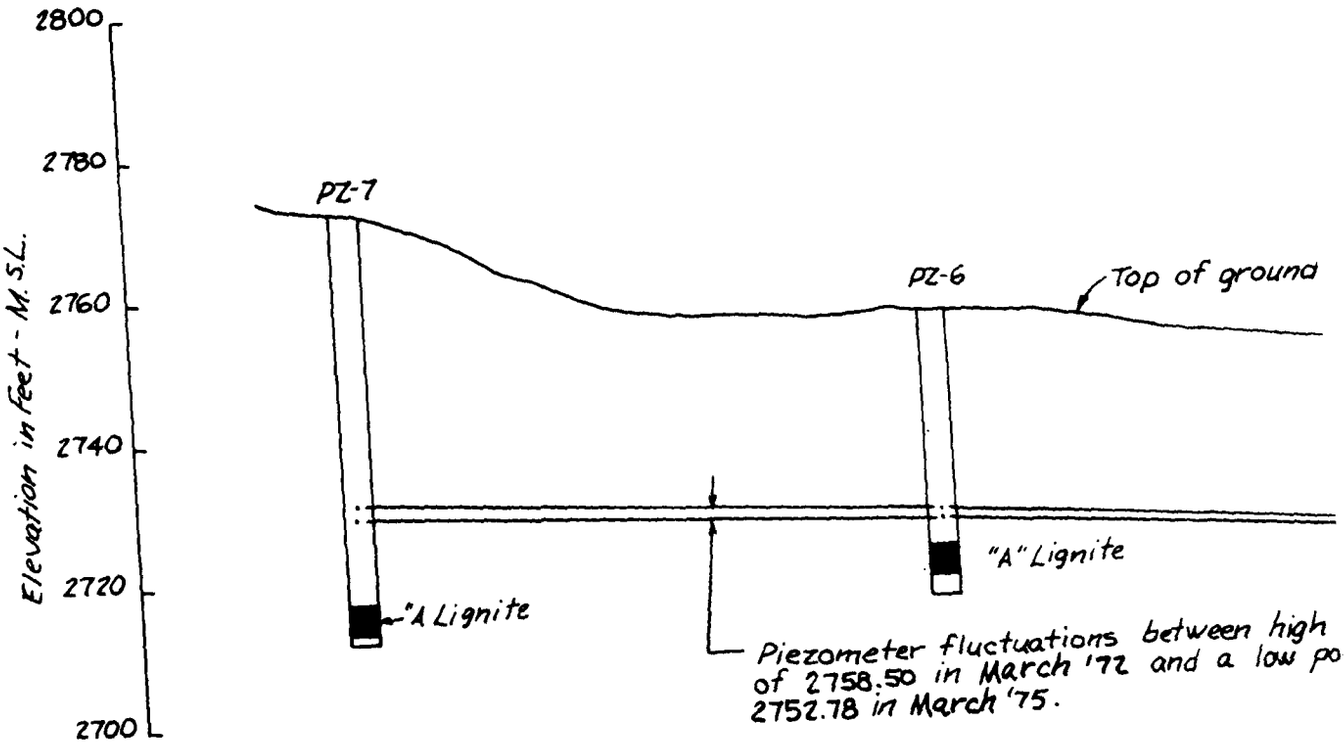
zometer fluctuations between high pool
2758.50 in March '72 and a low pool of
2.78 in March '75.

SECTION (B)

SCALE: VERT. 1INCH= 20 FEET
HORIZ 1INCH=100 FEET

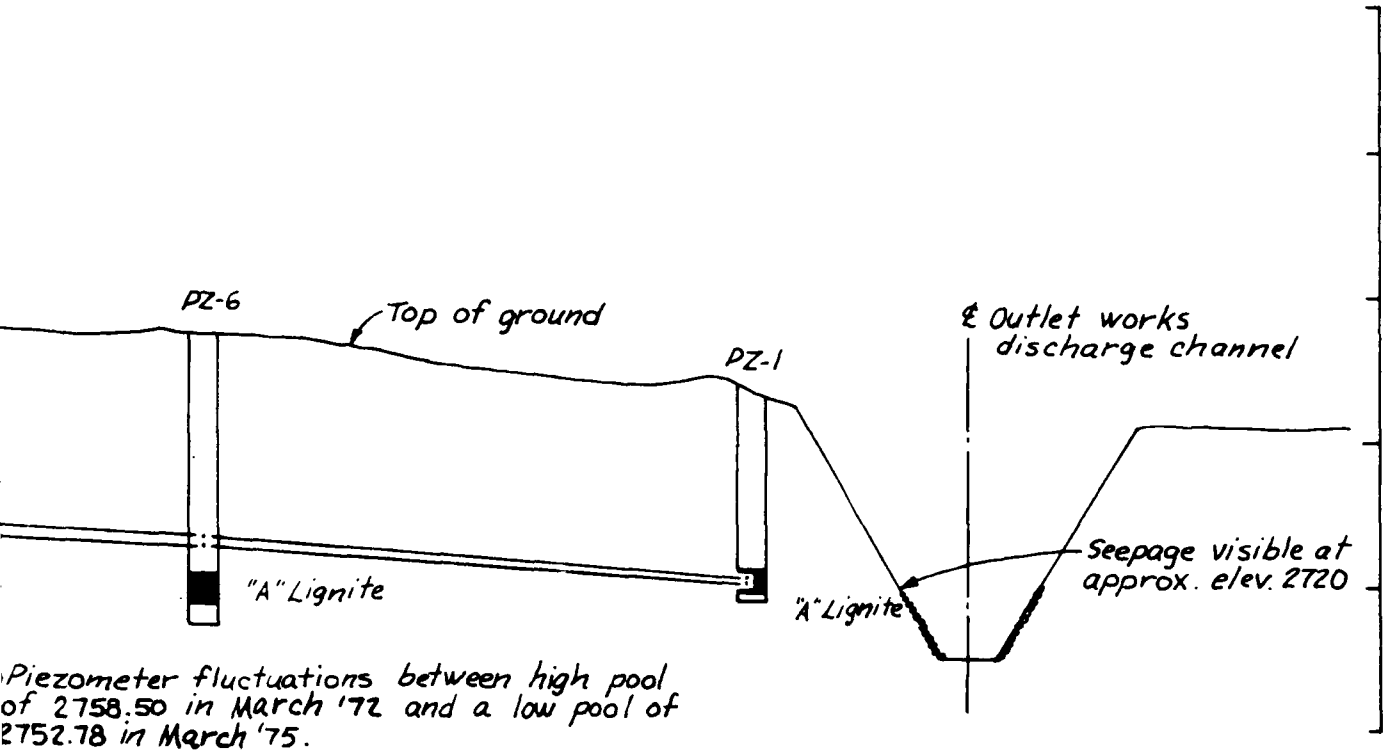
BOWMAN-HALEY DAM AND LAKE

PIEZOMETERS
SECTION "B"



SECTION C

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET



Piezometer fluctuations between high pool of 2758.50 in March '72 and a low pool of 2752.78 in March '75.

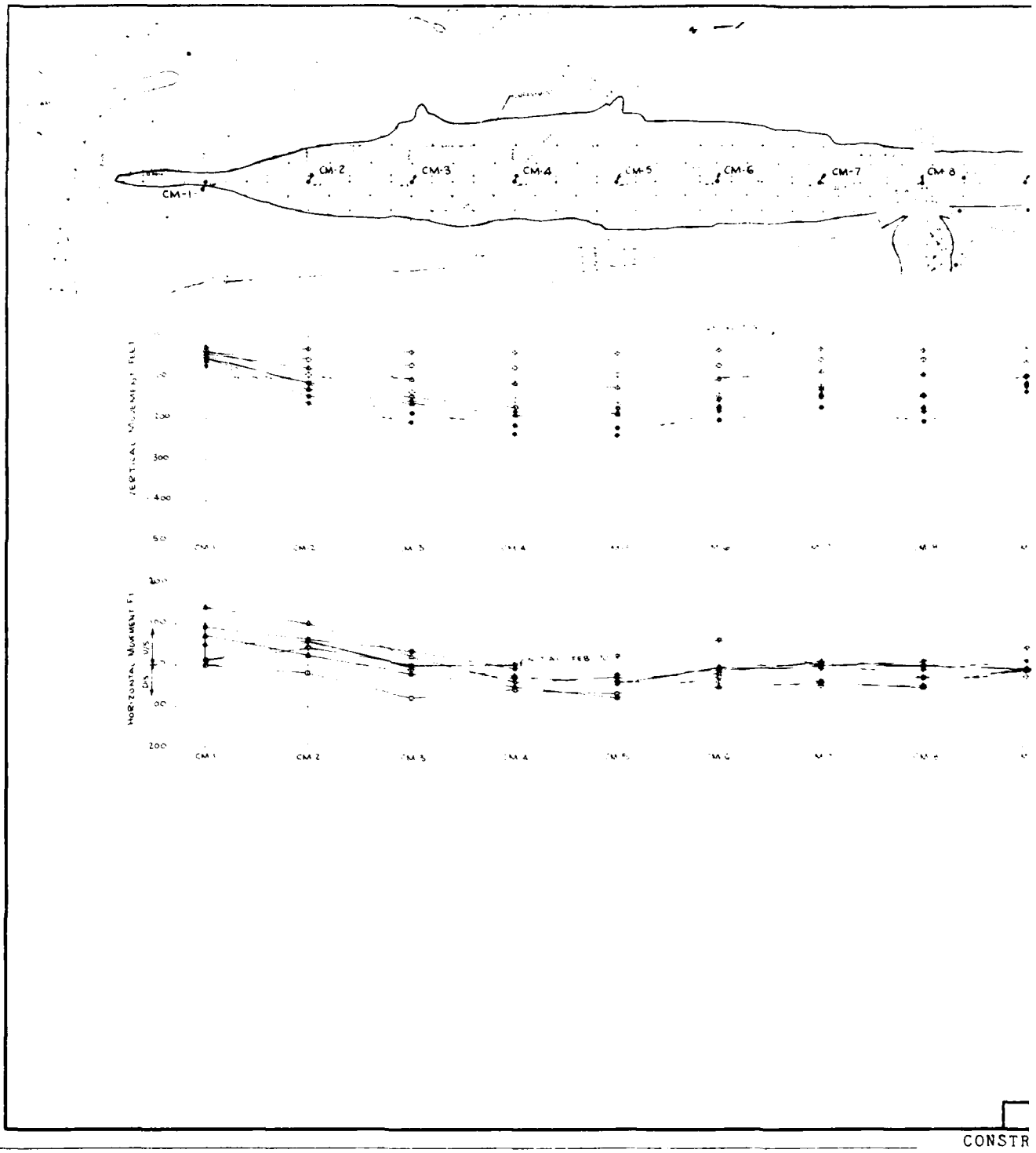
SECTION C

SCALE: VERT. 1 INCH = 20 FEET
HORIZ. 1 INCH = 100 FEET

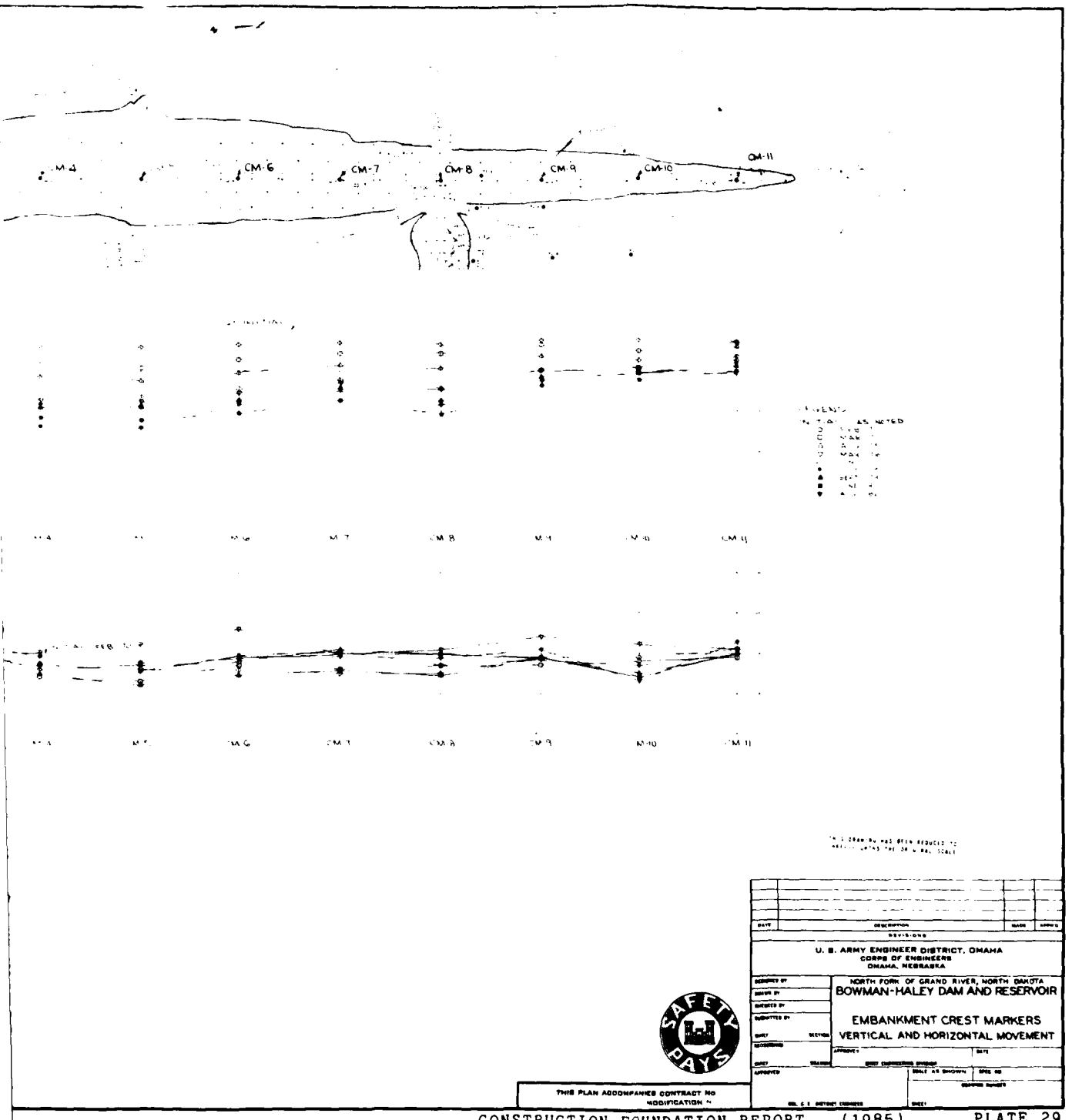
BOWMAN-HALEY DAM AND LAKE

PIEZOMETERS

SECTION C



CONSTR



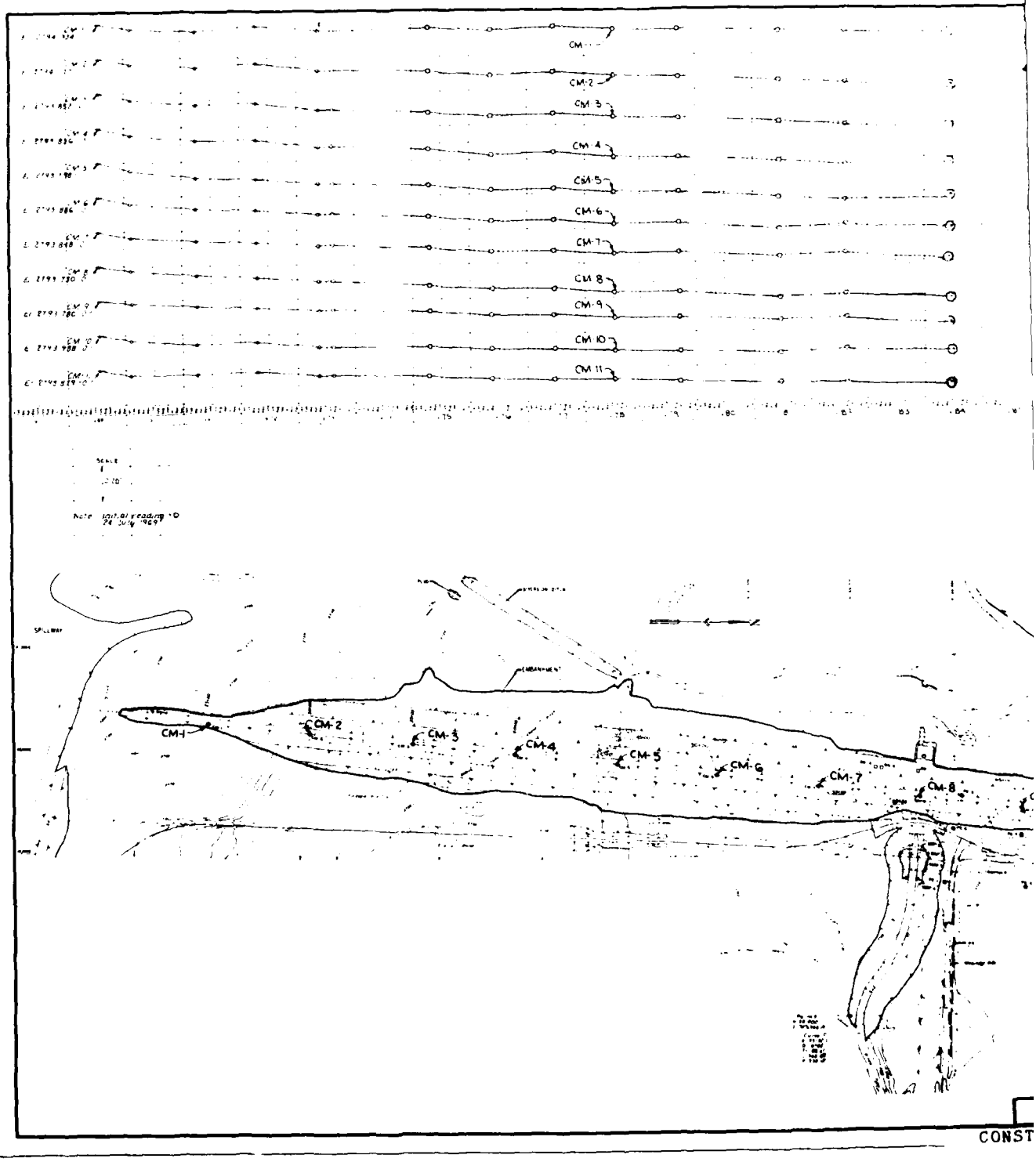
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

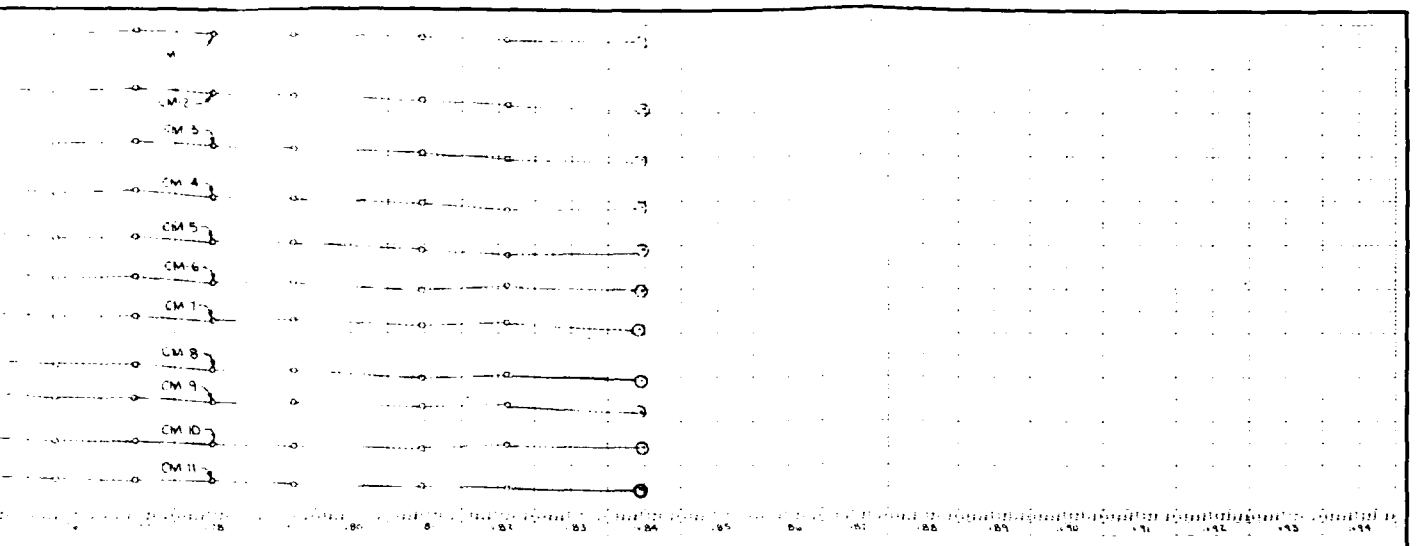
NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM AND RESERVOIR

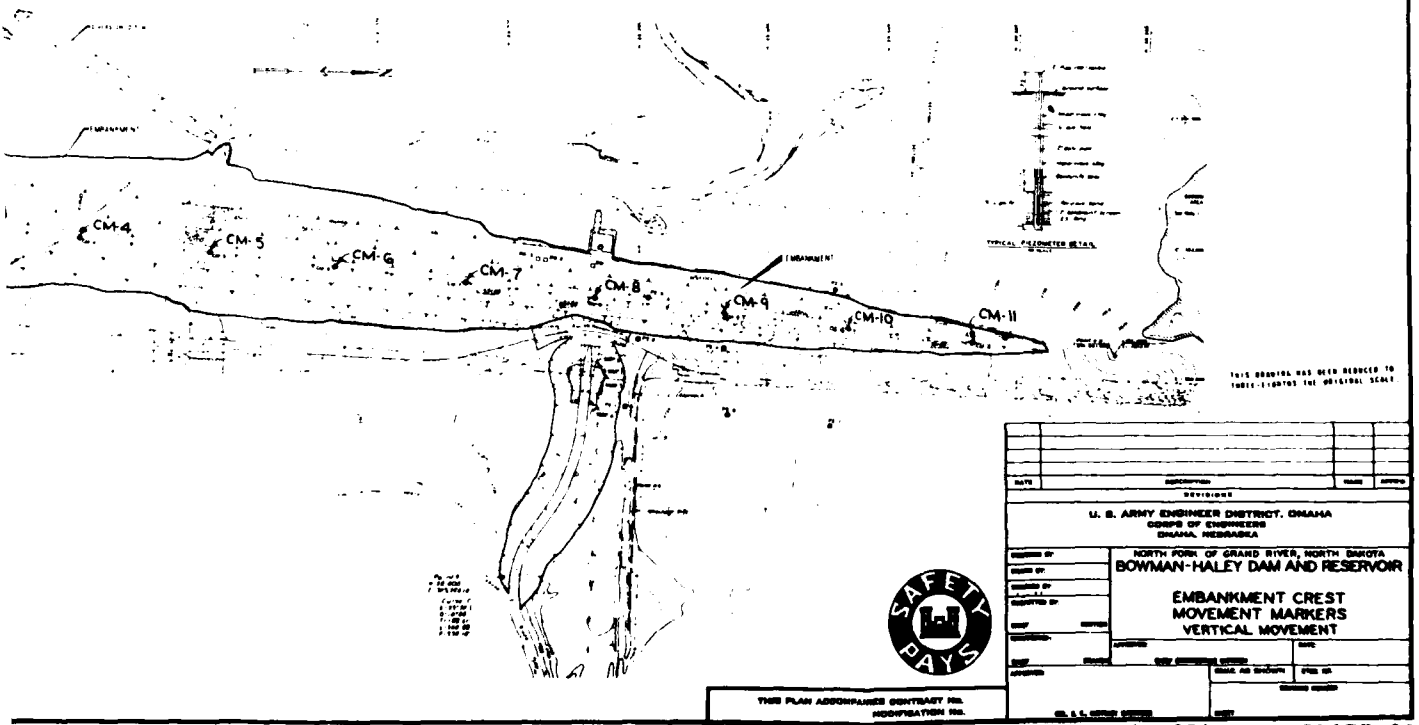
EMBANKMENT CREST MARKERS
VERTICAL AND HORIZONTAL MOVEMENT

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO
MODIFICATION NO


CM-1
CM-2
CM-3
CM-4
CM-5
CM-6
CM-7
CM-8
CM-9
CM-10
CM-11
SPILLWAY
EMBANKMENT
CM-1
CM-2
CM-3
CM-4
CM-5
CM-6
CM-7
CM-8





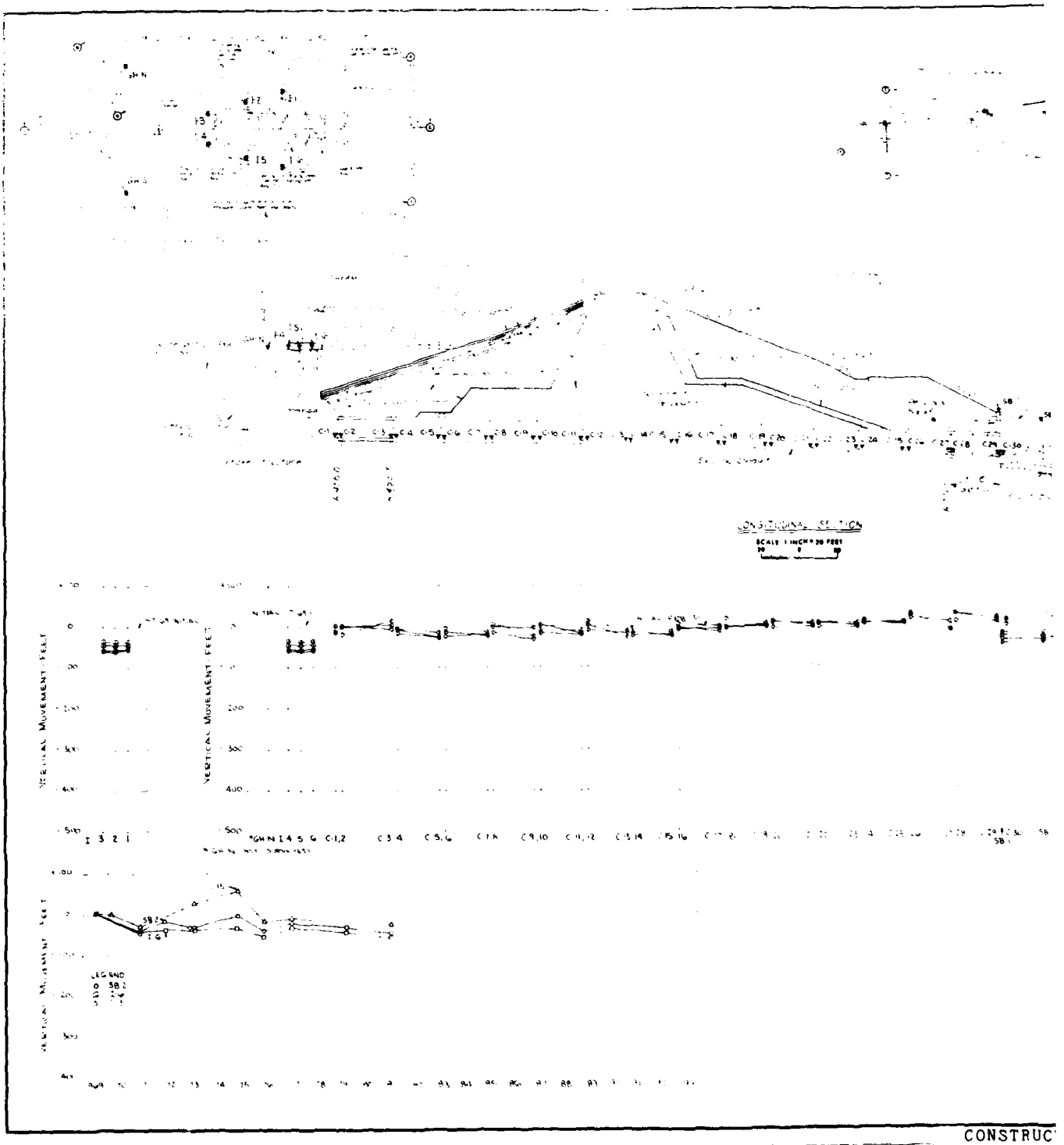
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM AND RESERVOIR

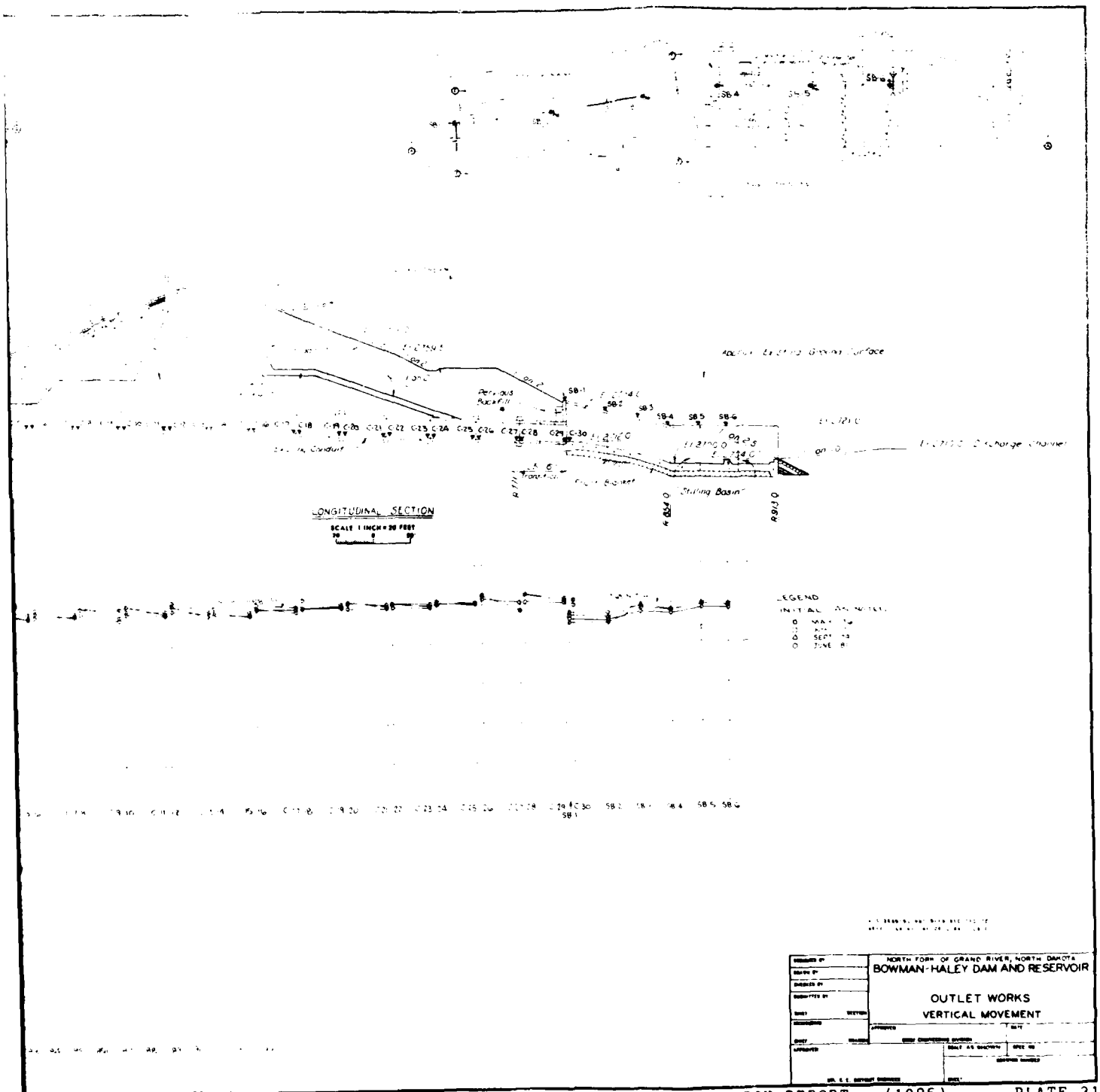
EMBANKMENT CREST
MOVEMENT MARKERS
VERTICAL MOVEMENT

SAFETY PAYS

THIS PLAN ACCOMPANIES CONTRACT NO.
MODIFICATION NO.

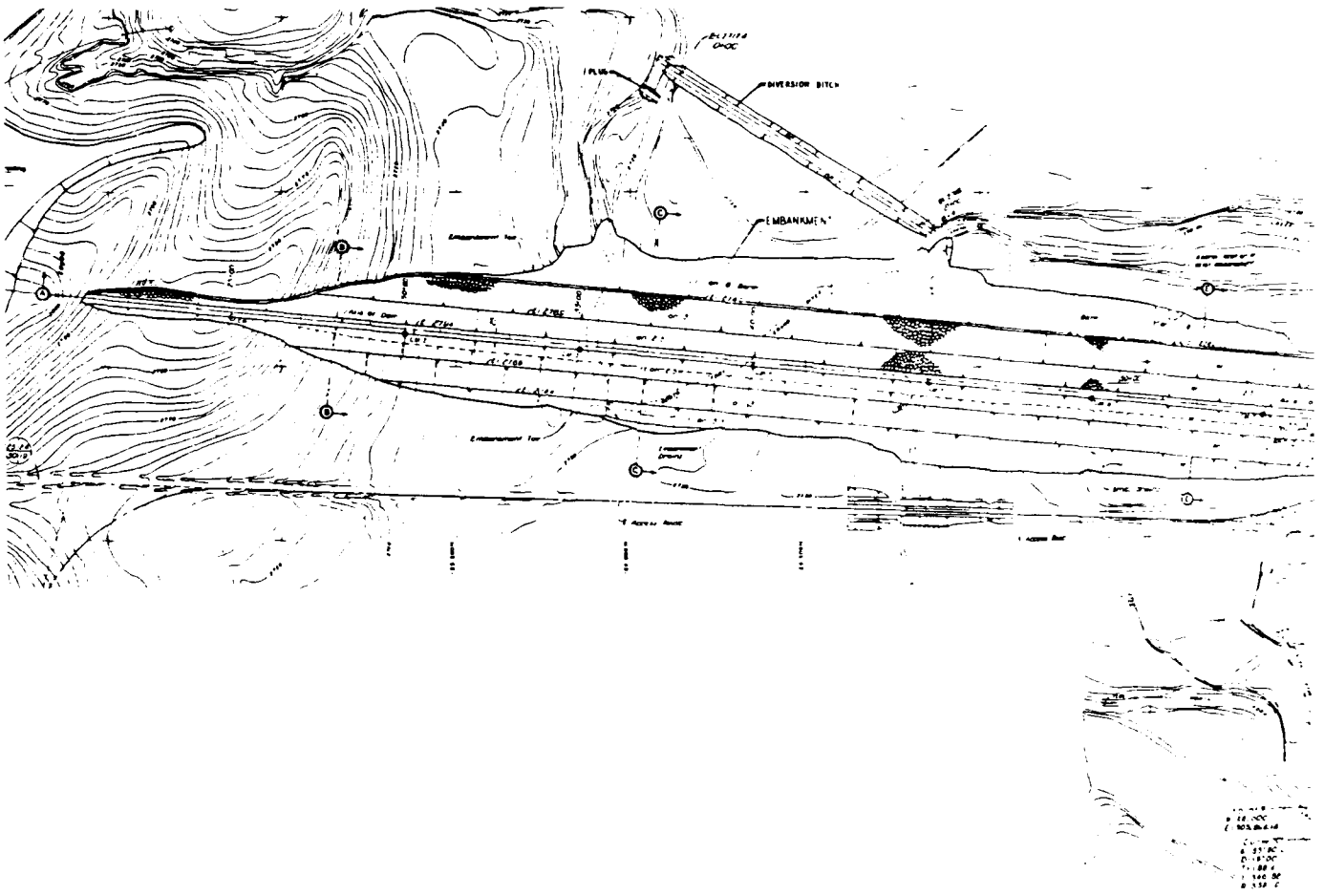

LONGITUDINAL SECTION
SCALE 1 INCH = 20 FEET
VERTICAL MOVEMENT FEET
LEGEND

CONSTRUC

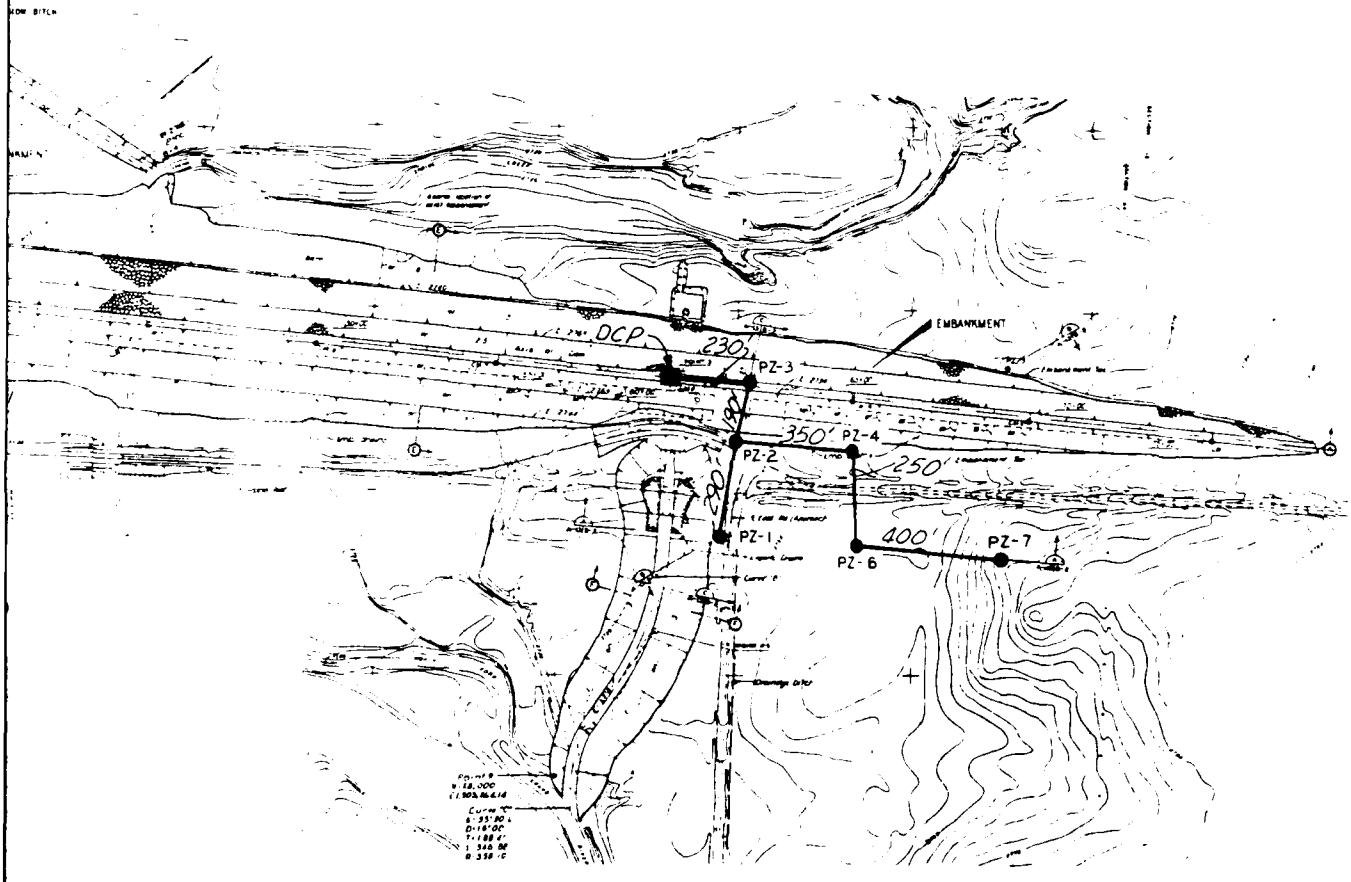


NORTH FORK OF GRAND RIVER, NORTH DAKOTA
BOWMAN-HALEY DAM AND RESERVOIR

OUTLET WORKS
VERTICAL MOVEMENT



SCALE. 1"= 400'



SCALE 1"= 400'

NORTH FORK OF GRAND RIVER

BOWMAN HALEY LAKE, NORTH DAKOTA

AUTOMATIC PIEZOMETER MONITORING SYSTEM

TRENCH LOCATION MAP

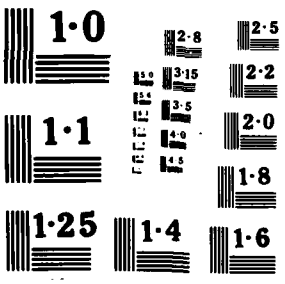
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

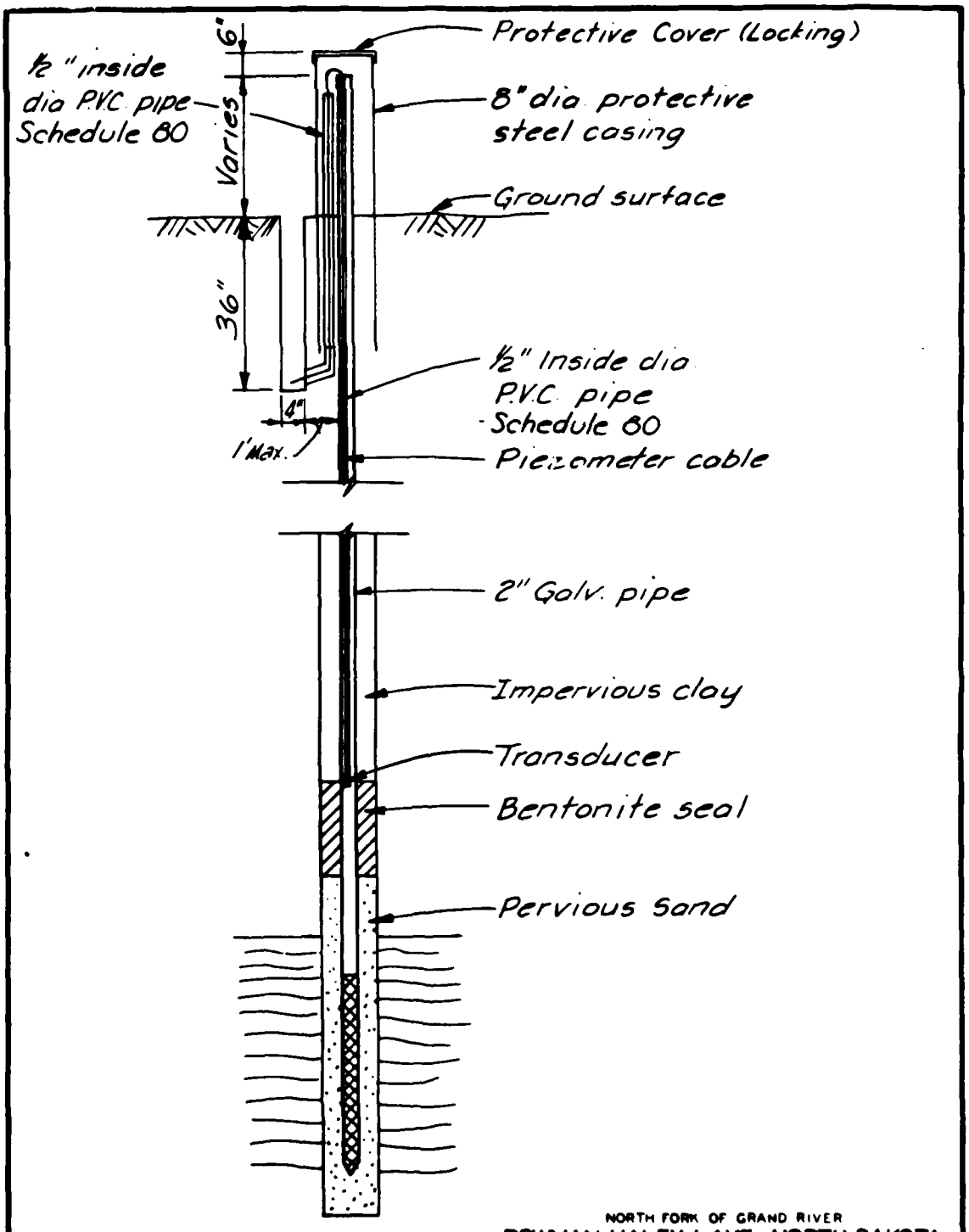
AD-A163 265 CONSTRUCTION FOUNDATION REPORT GRAND RIVER BOWMAN-HALEY 1/2
PROJECT NORTH DAKOTA VOLUME 1 TEXT DRAWINGS PHOTOS(U)
CORPS OF ENGINEERS OMAHA NE MAY 85

UNCLASSIFIED F/G 13/13 NL



END
DATE FILMED
2-86
DTIC


1·0
1·1
1·25
2·8
3·15
3·5
4·0
4·5
1·4
2·5
2·2
2·0
1·8
1·6



TYPICAL PIEZOMETER DETAIL

NO SCALE

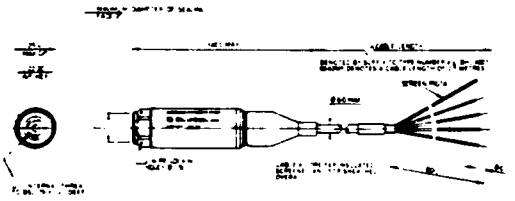
NORTH FORK OF GRAND RIVER
BOWMAN HALEY LAKE, NORTH DAKOTA
AUTOMATIC PIEZOMETER MONITORING SYSTEM
TYPICAL PIEZOMETER DETAIL
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

Specifications

Bell & Howell

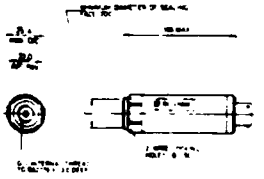
INPUT	
Type Number	BHL 4[illegible] integral cable [illegible]
Pressure Ranges	0.75 1 2 3 5 7 10 bar Absolute or Vented Gauge Reference 20 30 50 70 100 150 200 250 350 500 700 bar Sealed Reference
essure Limits	2 × rated pressure or 830 bar whichever is less when supplied for minutes will not cause a zero set exceeding 0.5% FRO
Electrical Configuration	4 wire system Output not isolated from input (see wiring diagram)
Supply	Rated 10V d.c. Operable 10 30V d.c. continuous 35V d.c. for 5 seconds maximum Consumption 22 mA maximum
Supply Protection	The transducer is protected against supply polarity reversal
OUTPUT	
Full Range Output (FRO)	5V ± 1% at + 25°C and rated supply (2mA maximum output current)
Residual Unbalance	0V ± 1% FRO at + 25°C and rated supply
Non-Linearity & Hysteresis	Maximum combined effect ± 0.5% FRO from best straight line
Resolution	Continuous
Output Resistance	50Ω maximum
Capacitive Loading	Up to 0.1 µF
Output Noise	5 mV peak to peak maximum
Supply Voltage Sensitivity	Less than 0.25% FRO/V for 10 to 30V d.c. supply
Output Protection	Short circuit of outputs or connections to negative supply line will not cause damage Short circuit of outputs to positive supply line for longer than 5 seconds not permitted
Output Limit	Output will not exceed 6.5V d.c.
ENVIRONMENTAL	
Temperature Range	− 10°C to + 100°C (compensated) − 54°C to + 120°C (operating)
Thermal Zero Shift	Maximum ± 0.018% FRO °C over compensated temperature range
Thermal Sensitivity Shift	Maximum ± 0.018% FRO °C over compensated temperature range
Vibration (35 g peak 5-2000 Hz 12 mm double amplitude maximum)	Response will not exceed 0.06% FRO/g for 0.75 bar range decreasing logarithmically with pressure range to 0.015% FRO/g for 700 bar range
Acceleration (100 g steady)	Response will not exceed 0.05% FRO/g for 0.75 bar range decreasing logarithmically with pressure range to 0.01% FRO/g for 700 bar range
Mechanical Shock	100 g half sine wave pulse for 11 milliseconds will not damage the transducer
External Pressure	External pressure (not applied to pressure port) from 0 to 20 bar A will not affect the transducer (Absolute and Sealed Reference units only)
Humidity	BHL-4004-00 Operable to 95% R.H. at up to 38°C BHL 4003-00 Fully immersible to 200 m
PHYSICAL	
Pressure Connection	G¼ internal thread to BS 2779 13 mm deep
Electrical Connection	BHL 4003-00 Integral sealed cable assembly in standard lengths of 1 metre terminating in flying leads BHL 4004-00 6 pin size 10 bayonet lock connector
Isolation	All connections isolated from case Insulation resistance greater than 500 MΩ at 85V d.c.
Materials in Contact with Pressure Media	17-4 PH and 15-5 Mo stainless steels for ranges 5 bar and below 17-4 PH stainless steel for ranges 7 bar and above
Included Accessories	Calibration Record Dowty Seal L499207 0002 BHL 4004-00 only detachable connector to MS 3116F 10-6S
Optional Accessories	Screw in stainless steel pressure fitting adaptors or welded on adaptors to special order Additional cable on BHL-4003-00 Specify total length required in metres

BHL 4003



Weight 245g including one metre cable

BHL 4004



Weight 165g

FUNCTION	BHL-4003 WIRE COLOUR	BHL-4004 PIN REFERENCE
Positive Excitation	RED	A
Positive Output	YELLOW	B
Negative Output	BLUE	C and F
Negative Excitation	WHITE	D and E

Due to continuous development we reserve the right to amend specifications without notification

United States of America, Bell & Howell Co Electronics & Instruments Group 360 North Sierra Madre Villa [illegible] California 91109

[illegible] Bell & Howell Australia (Pty) Ltd [illegible] 4778 55-65 Murray Street Sydney [illegible] South Wales 2000

England, Bell & Howell Ltd Lennox Road Basingstoke Hampshire RG22 4AW

France, Bell & Howell France S.A. Electronics & Instruments Division 112 Rue Des Solets Silic 138 94523 Rungis Cedex

Italy, Bell & Howell Italia SpA Via Invergo 6 20151 Milan

Netherlands, Bell & Howell GmbH Vlaardingweg 23 3044 CJ Rotterdam Postbox 10054 3004 AB Rotterdam

South Africa, Bell & Howell South Africa (Pty) Ltd Micro House 101 Jula Street P.O. Box 31239 Braamfontein Johannesburg 2001

West Germany, Bell & Howell GmbH Electronics & Instruments Division 6360 Friedberg Postfach 1230

A comprehensive network of specialised representatives provides full sales and service facilities in other countries

Printed in the United Kingdom by Optichrome Ltd

PHOTOS



PHOTO 1. July, 1964. View toward South at Dam Site Prior to Construction



PHOTO 2. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.

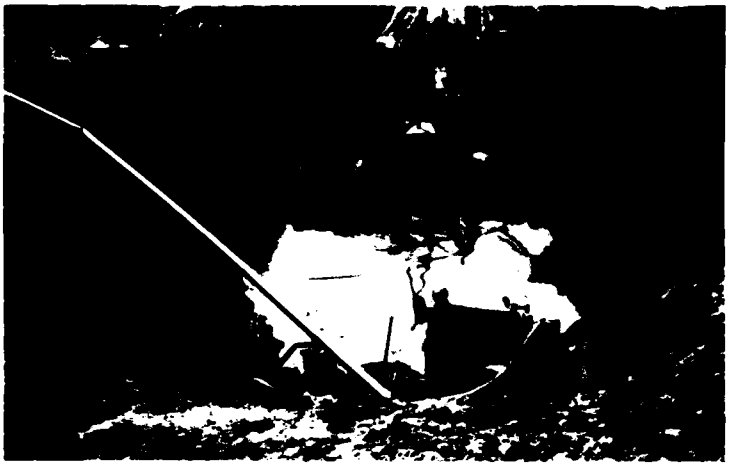


PHOTO 3. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 4. September, 1966, Backfull Operations in Cut-off Trench-Closure Section, Main Embankment.



PHOTO 5. September, 1966. Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 6. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 7 September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment



PHOTO 8. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 9 September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment.



PHOTO 9A. September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment

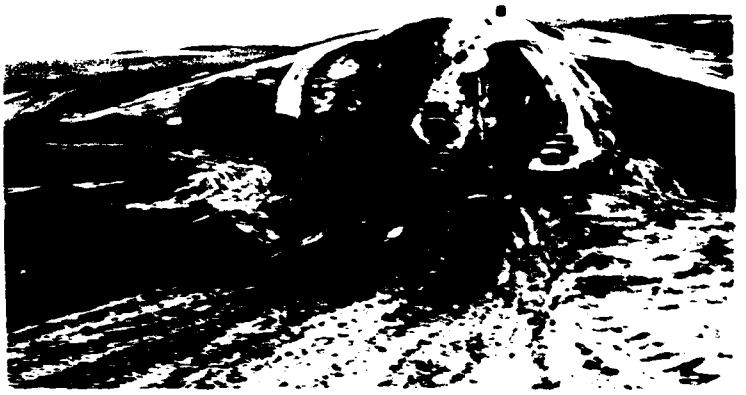


PHOTO 9B September, 1966, Excavation of Cut-Off Trench-Closure Section, Main Embankment



PHOTO 10. Conduit Construction

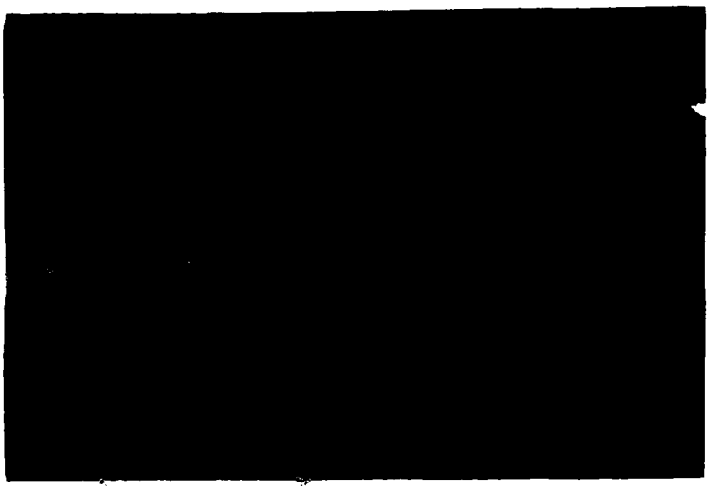


PHOTO 11. September, 1966, Trenching for Outlet Works



PHOTO 12 Upstream Portion of Stilling Basin With Fill Placed on Conduit.

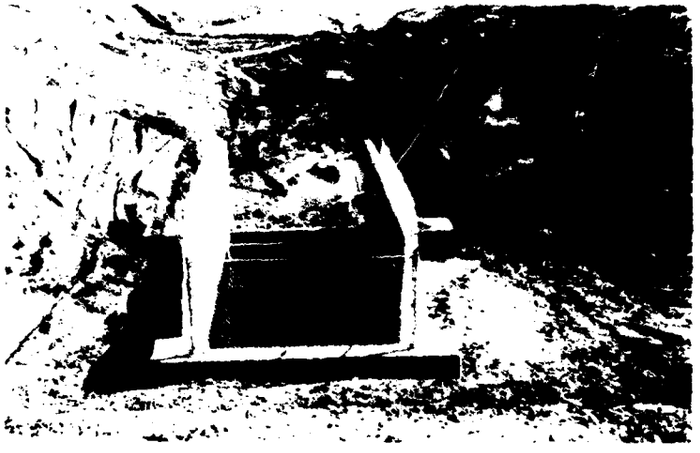


PHOTO 13. October, 1966, View East of Stilling Basin After Substantial Backfill Placement.



PHOTO 14. August, 1966, N.E. Corner of Stilling Basin- View Toward S.E.



PHOTO 15. Stilling Basin, Showing Foundation, Slab, and Wall Reinforcing-View is East



PHOTO 16. August, 1966, Stilling Basin Slab Pour-View is N. W.



PHOTO 17. September, 1966, Spillway-Soil Cement Scour Cut-Off Prior to Watering and Covering. View is to the South.



PHOTO 18. September, 1966, Beginning to Place Soil Cement in Spillway Cut-Off Trench. View is to the South



PHOTO 19. September, 1966, Spillway-Lignite in Scour Cut-Off Excavation.

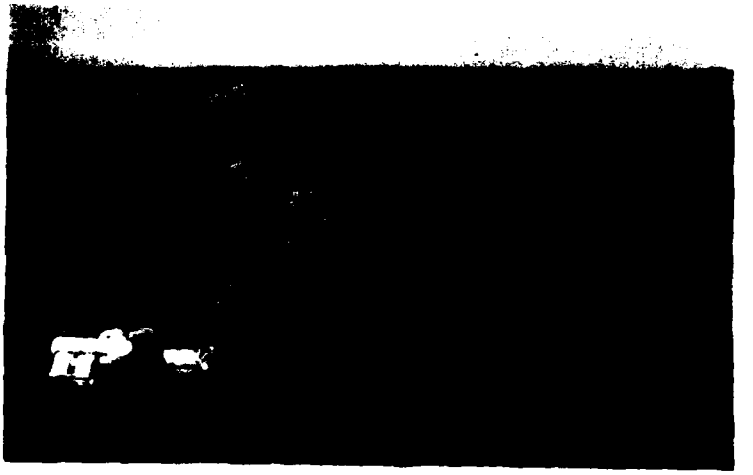


PHOTO 20. September, 1966, Spillway Scour Cut-Off Excavation



PHOTO 21. September, 1964, Outlet Works-Conduit Invert Collar Excavation.



PHOTO 22. August, 1964, Outlet Works-Excavation for Conduit Collar Invert, 17% Completion



PHOTO 23. November, 1964, Outlet Works Conduit, 90% Backfilled. View is East.



PHOTO 24. April, 1967, Spillway Excavation Showing Concretionary Type Rock Encountered.



PHOTO 25. April, 1967, South Slope of Spillway Showing Concretionary Rock in Place.

END

DATE
FILMED

2-86

DTI